

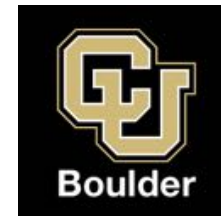
# Observational Signatures of Magnetic Reconnection in the Extended Corona

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SabriNA SAverage,  
Matthew J. West, Daniel B. Seaton



Royal Observatory  
of Belgium



# Supra-Arcade Downflows (SADs) Observations



Fig 1

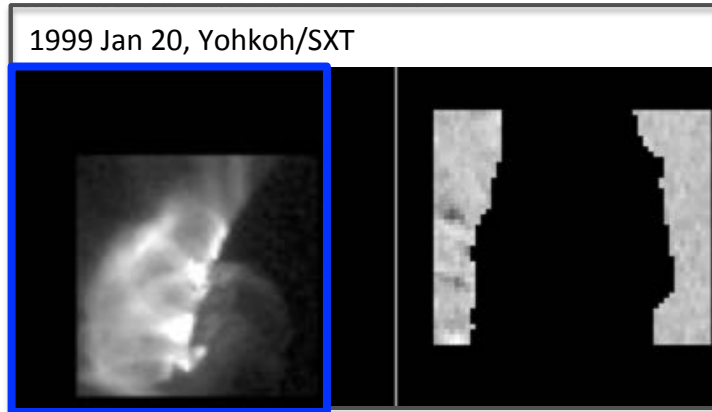


Fig 2

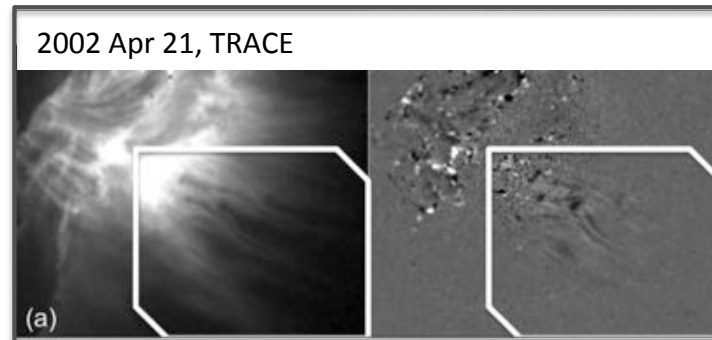


Fig 3

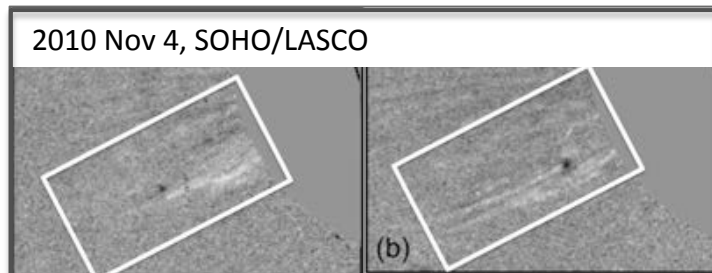
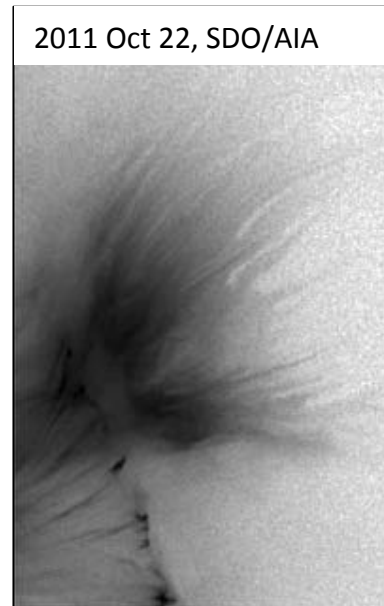
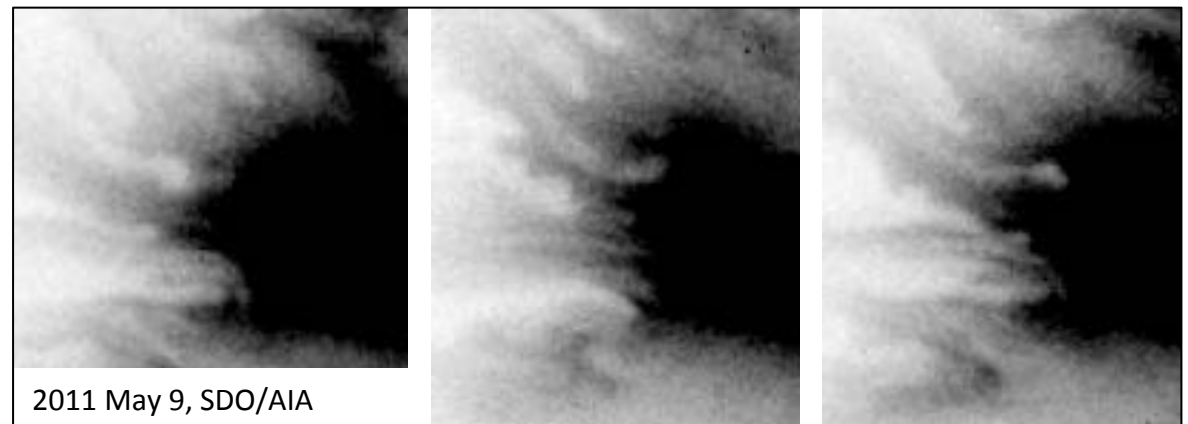


Fig 4

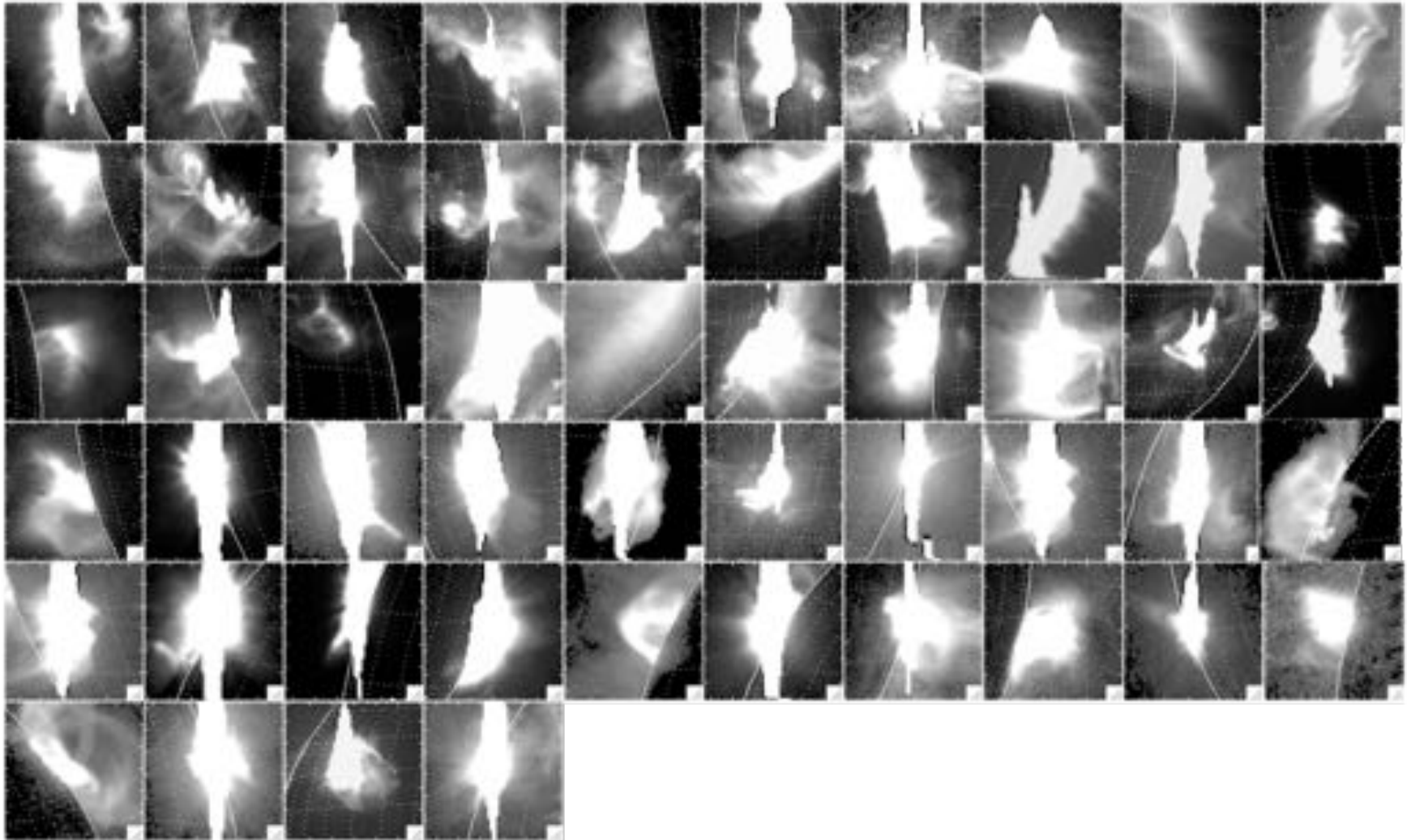


- Teardrop-shaped **voids** observed to travel sunward through the bright, hot fan extending outward along the spine of developing post-flare arcades.
- Observed with high-temperature instrumentation (EUV, X-ray) & white-light coronagraph (density)
- LONG DURATION EVENTS

Fig 5

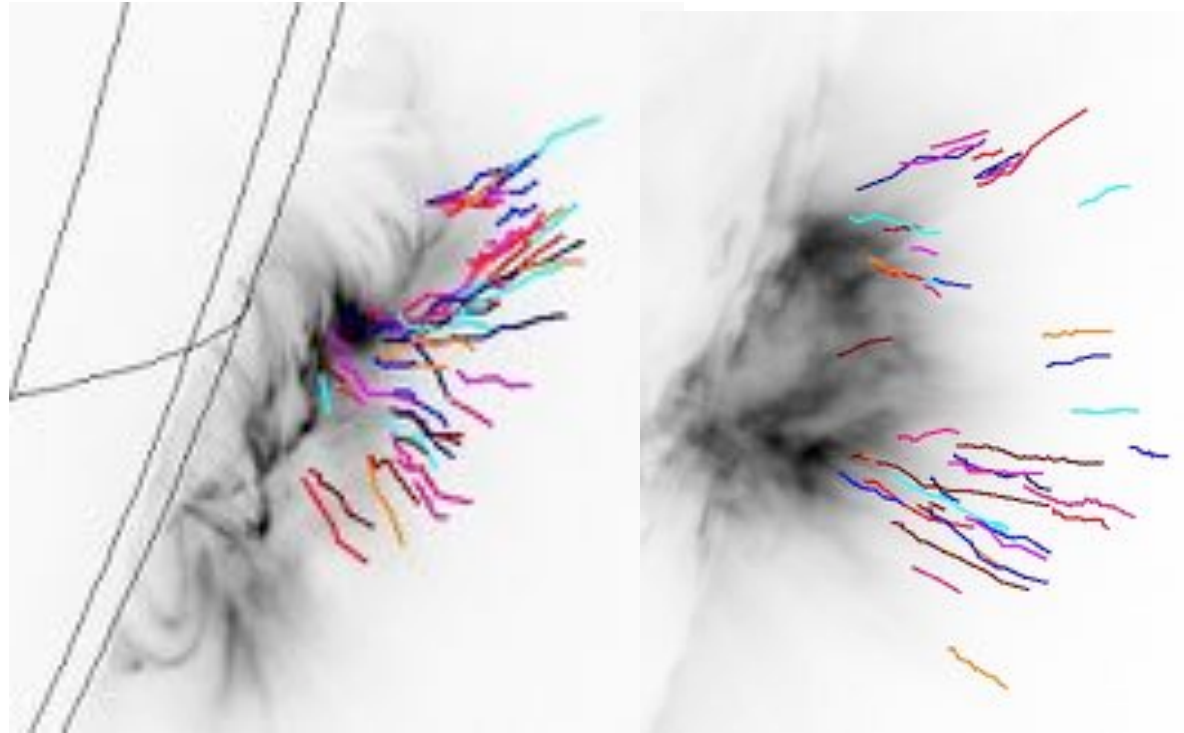
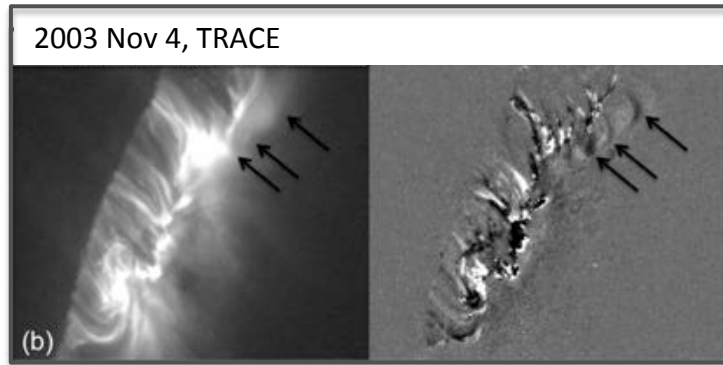


# Supra-Arcade Downflows (SADs) Observations



# Supra-Arcade Downflowing Loops (SADLs) Observations

Fig 1



# Supra-Arcade Downflowing Loops (SADLs) Observations

Fig 1

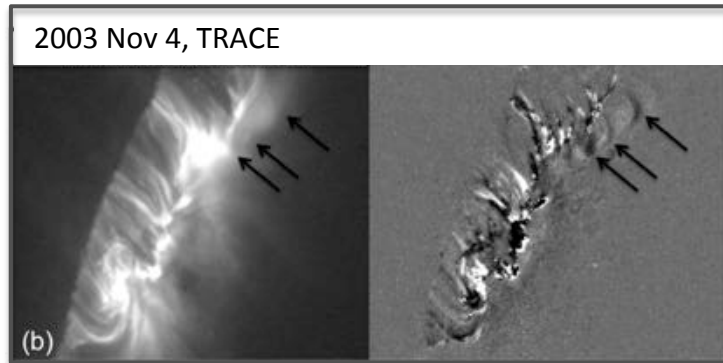
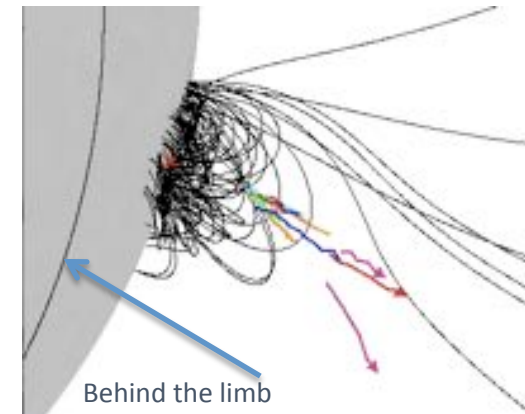
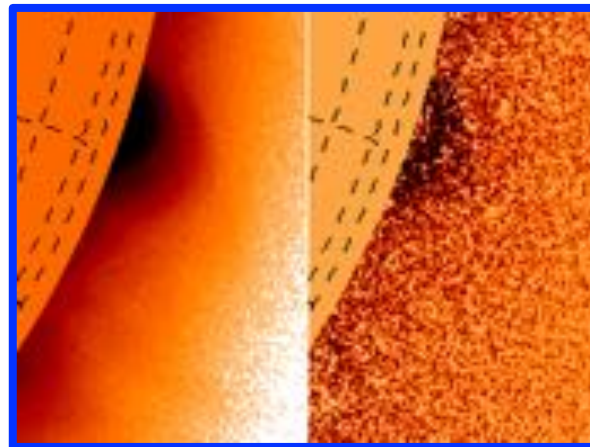
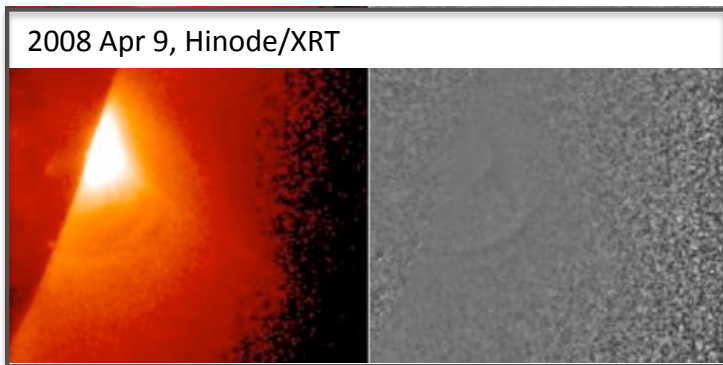


Fig 2





# Supra-Arcade Downflowing Loops (SADLs) Observations

Fig 1

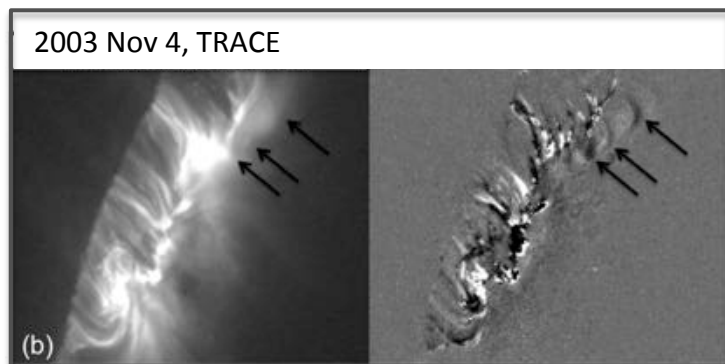
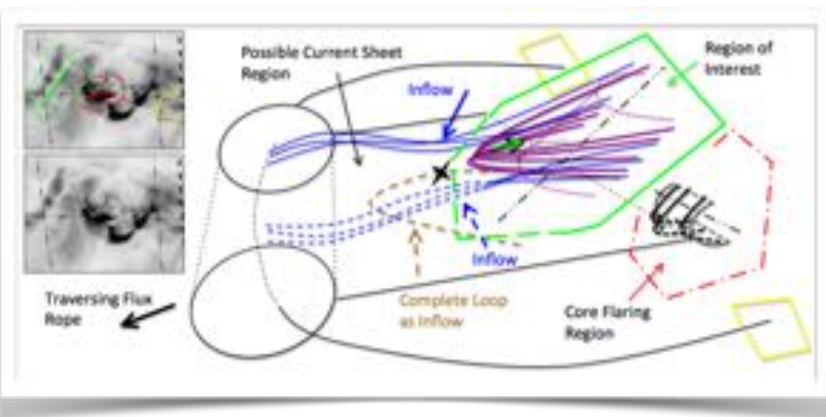
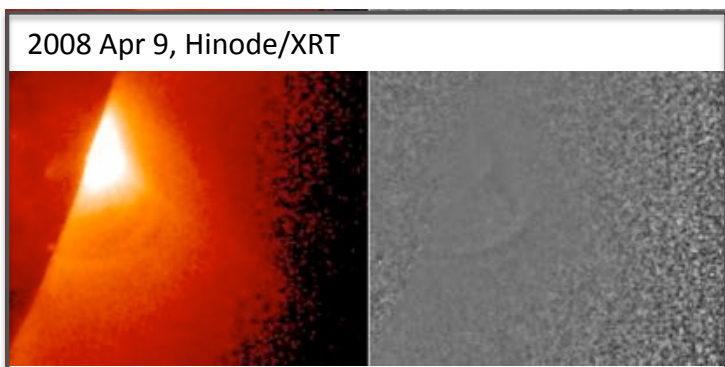


Fig 2



2010 Nov 3, SDO/AIA

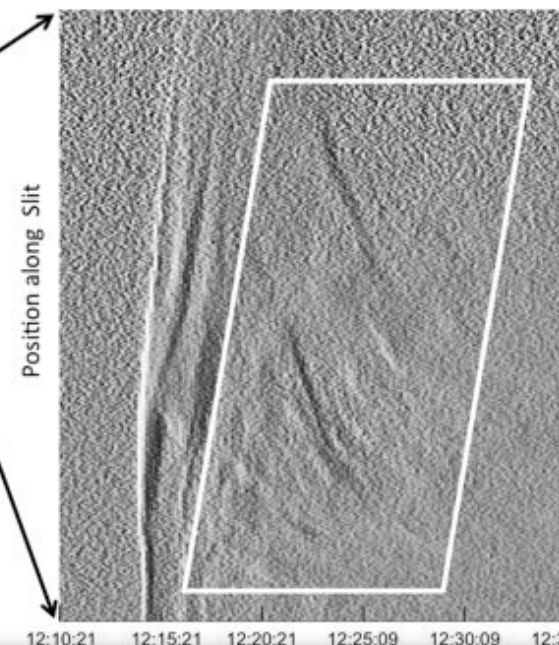


Fig 3

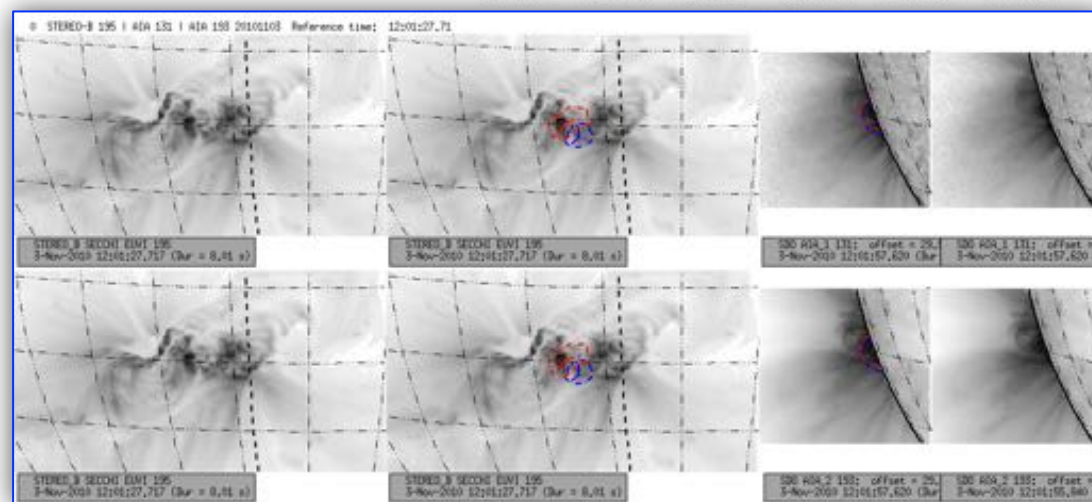


Fig 1: Savage & McKenzie 2011

Fig 2: Savage et al. 2010

Fig 3: Savage et al. 2012

# Different from Plasmoid Observations

- Coherent 'bubble' of **emitting** plasma held together by magnetic fields.
- Observed with broadband-temperature instrumentation (EUV, X-ray, Hard X-ray) & white-light coronagraph (density)
- ✓ "First they grow, then they go." – Lorenzo Sironi

Fig 1

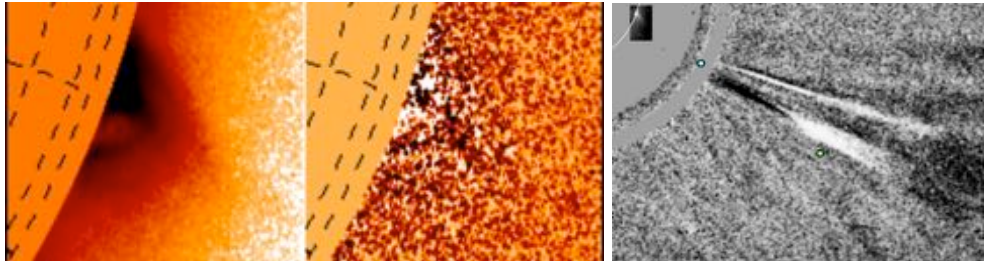


Fig 2

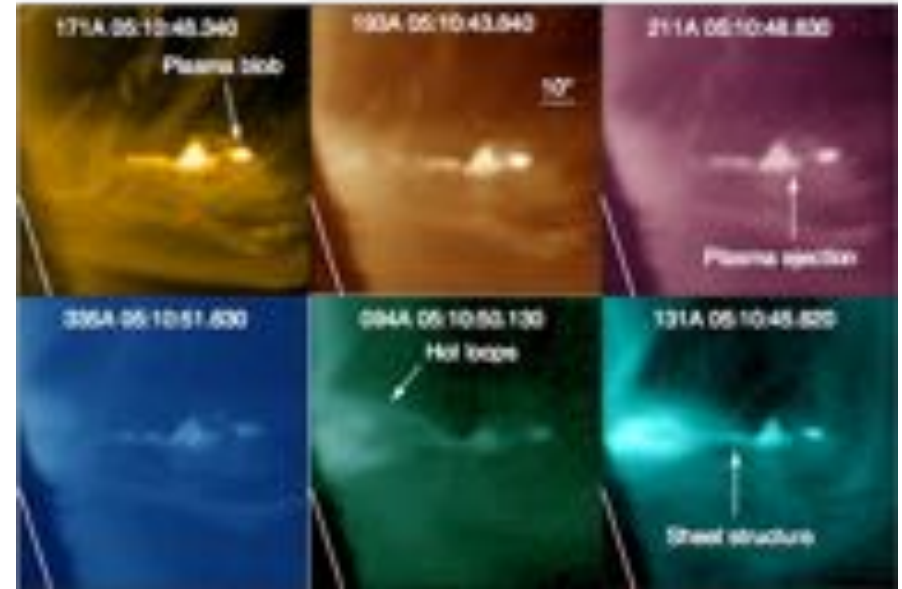
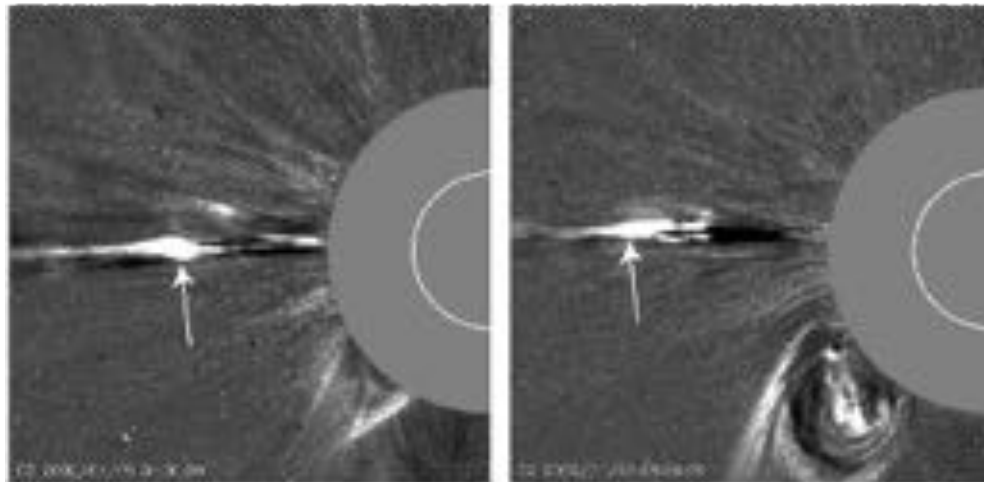


Fig 3

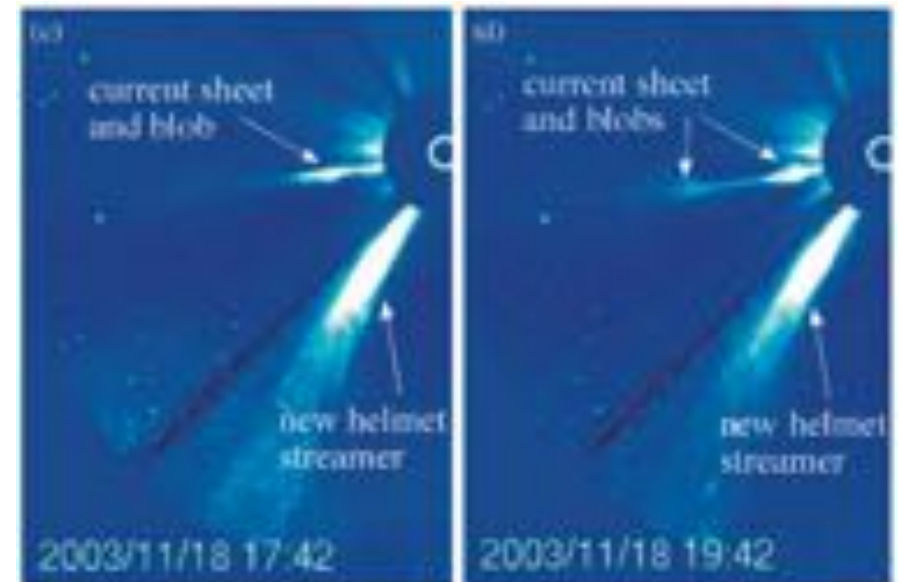


Fig 4



# Example Models & Simulations

Fig 1

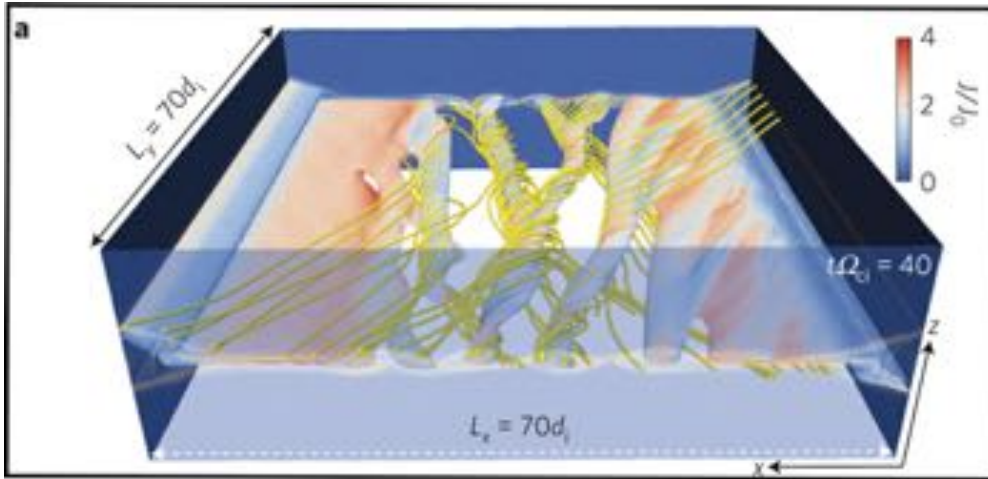
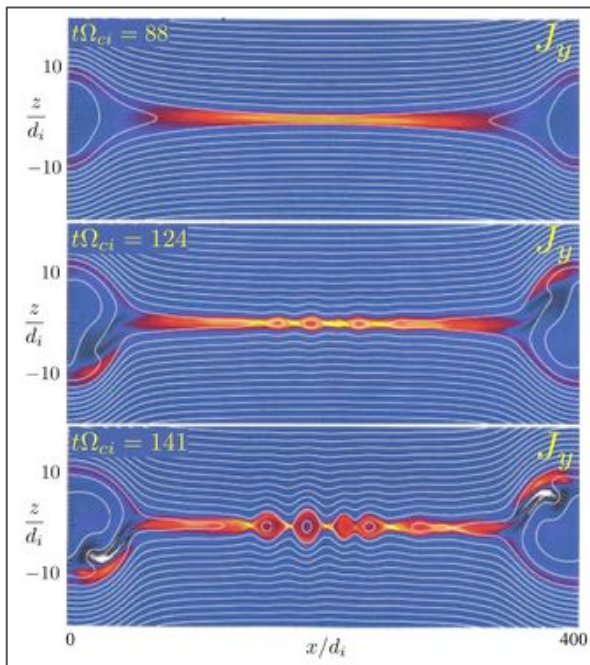
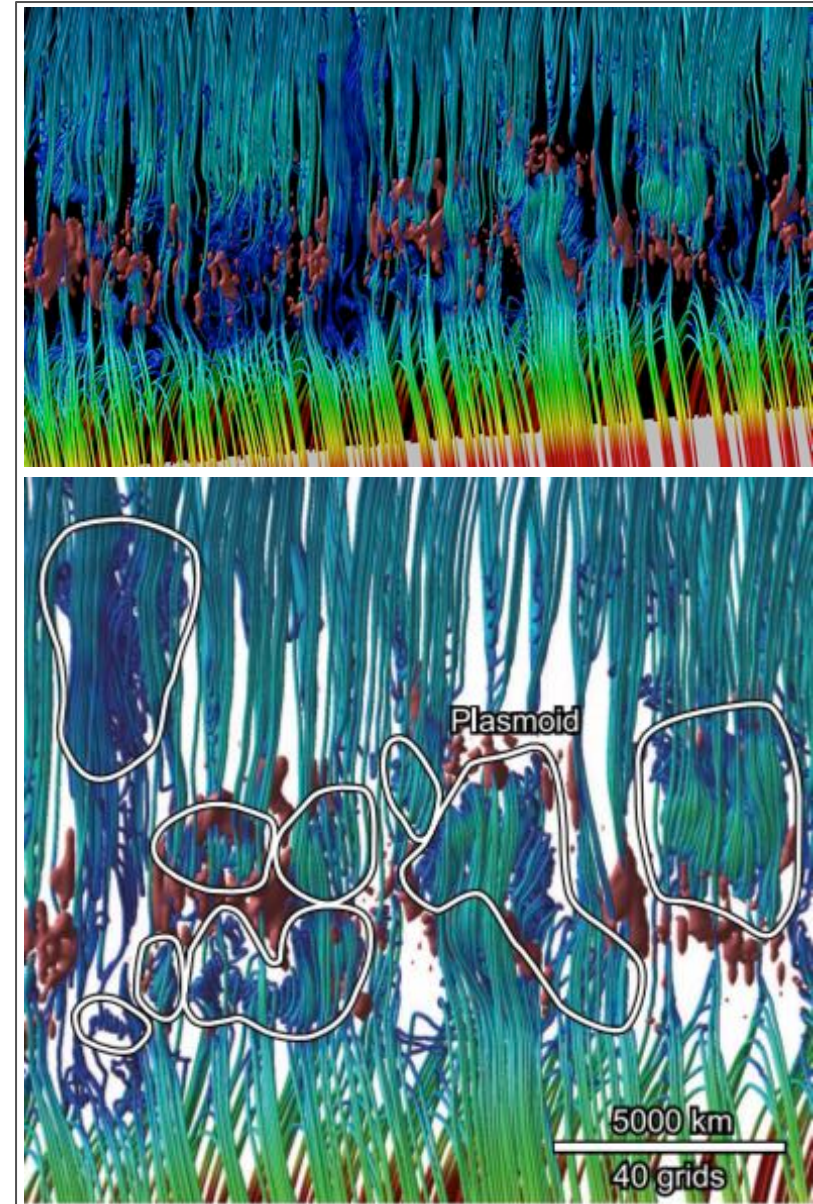


Fig 2



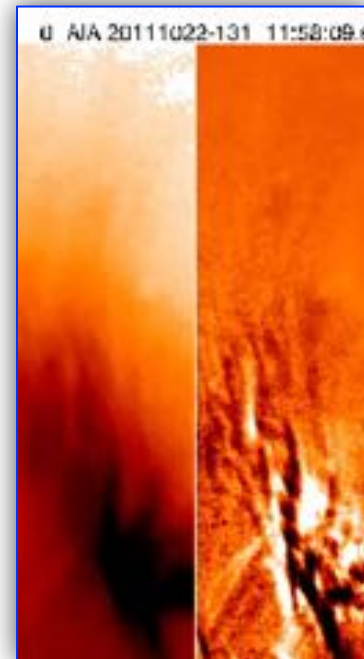
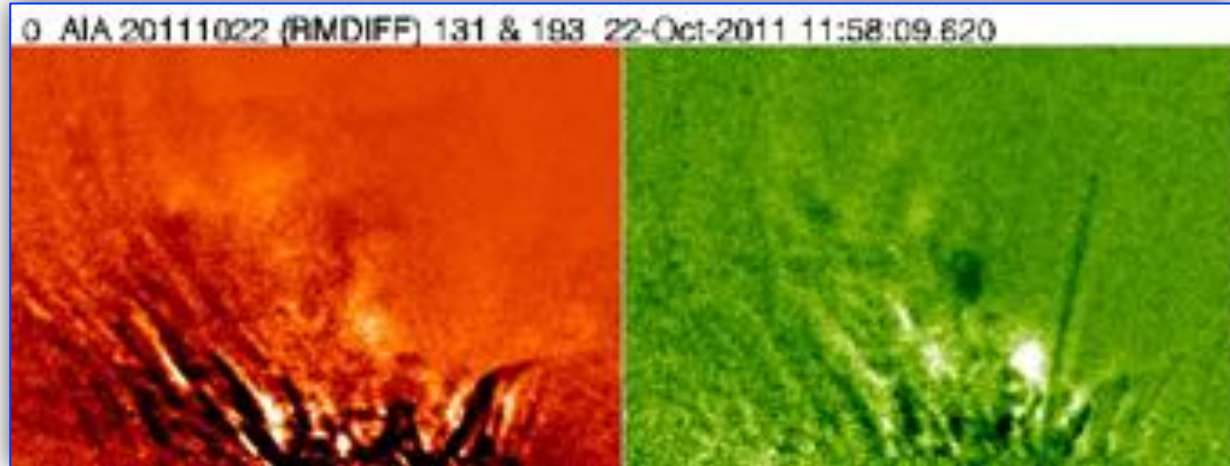
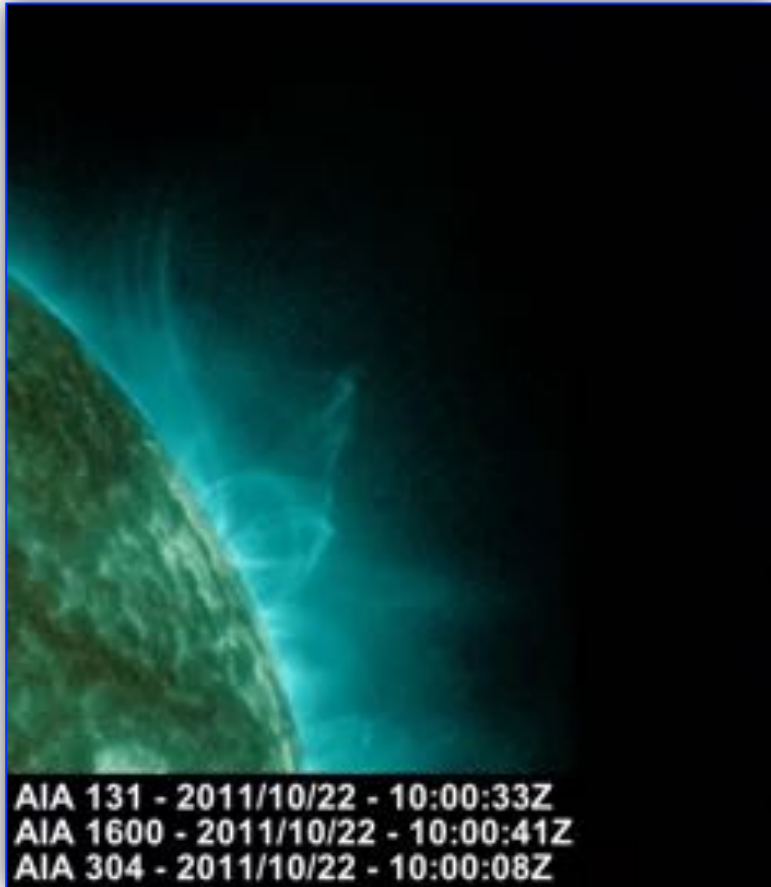
- Thin flux tubes created during the reconnection process across the current sheet.
- Plasmoids a 3-D product of reconnection concurrent to single loop creation.

Fig 3



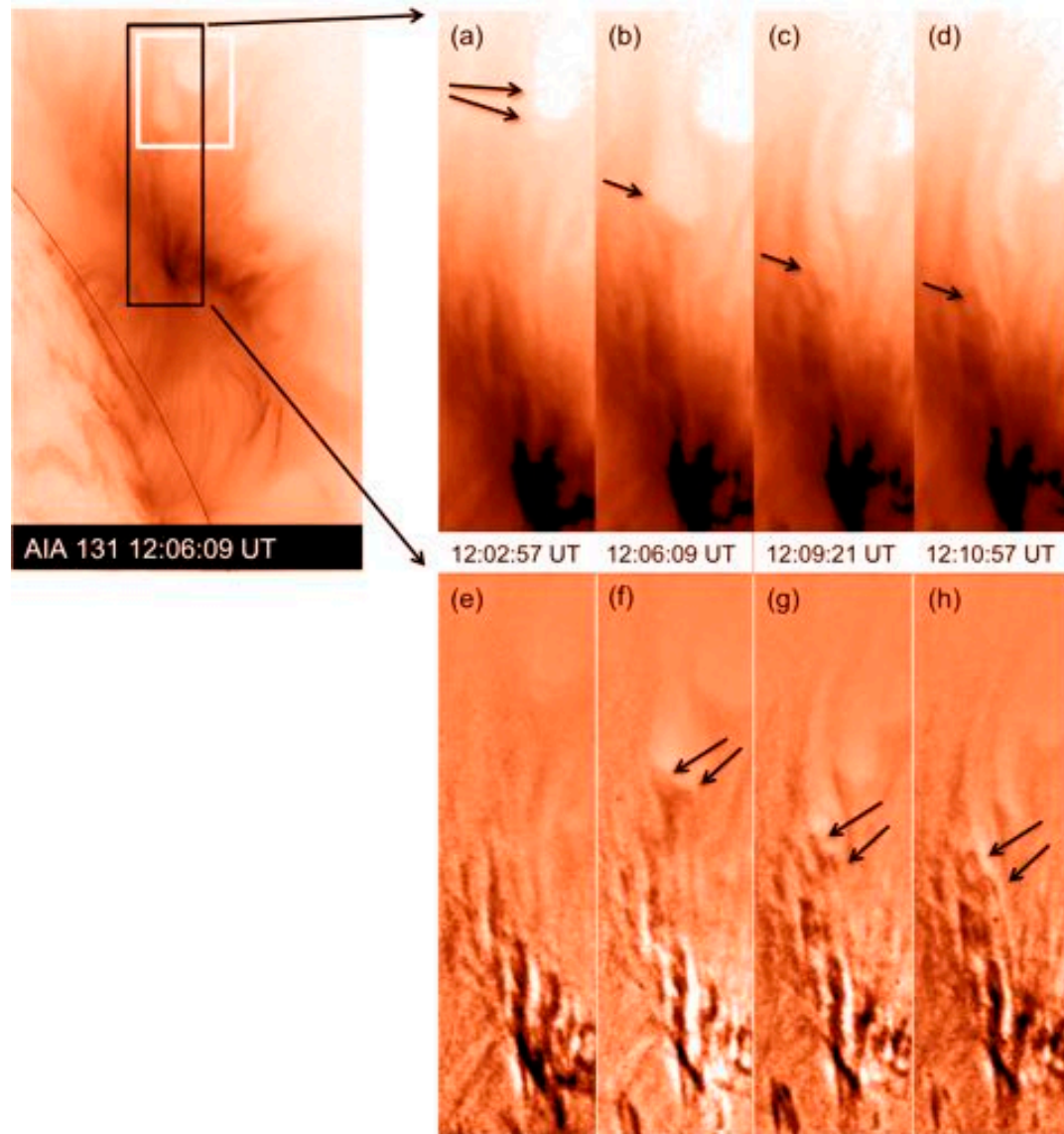


# SADs + SADLs



# SADs + SADLs

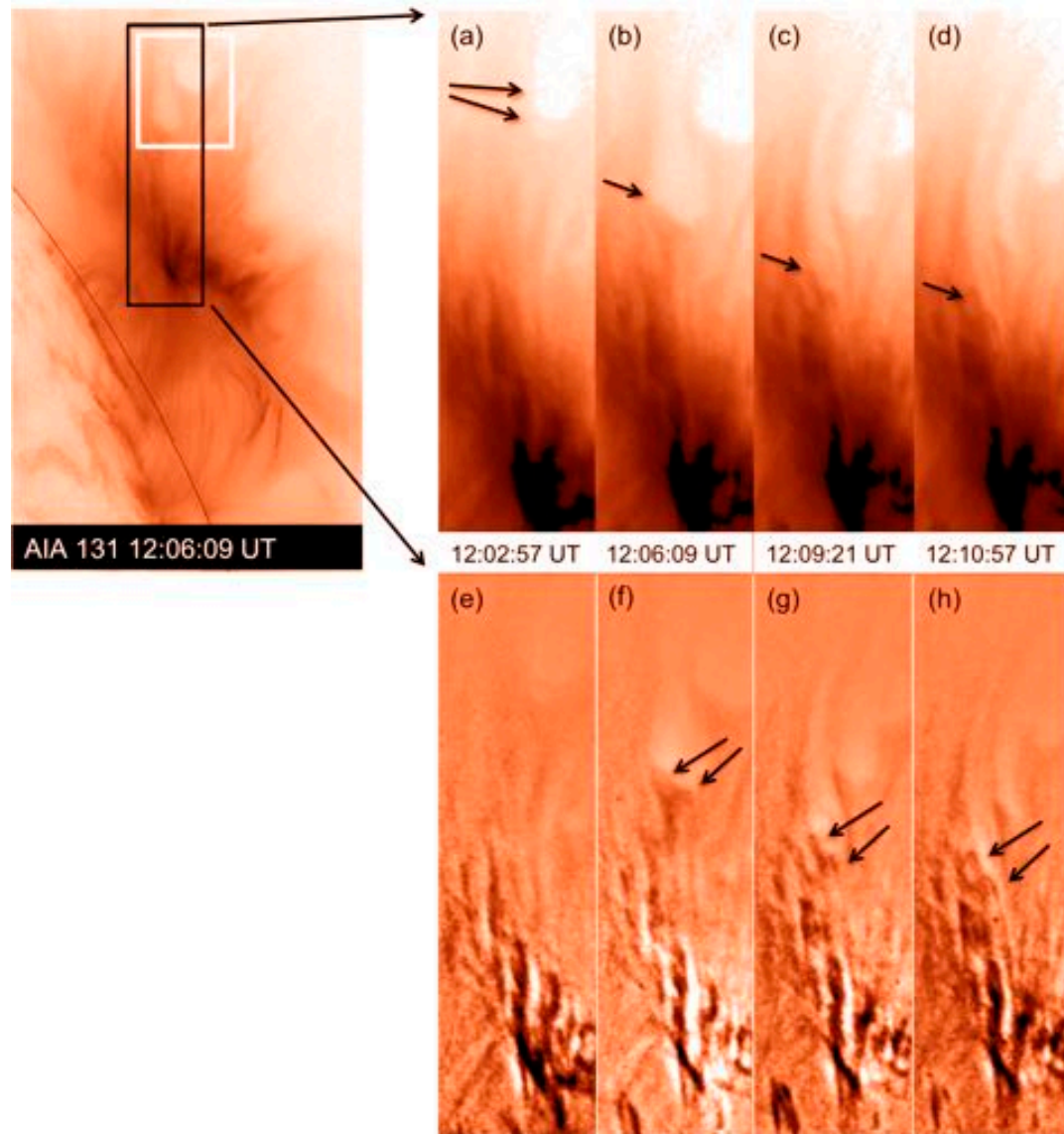
Fig 1



- SADs appear to be voids created by loops (SADLs) shrinking through the fan plasma.

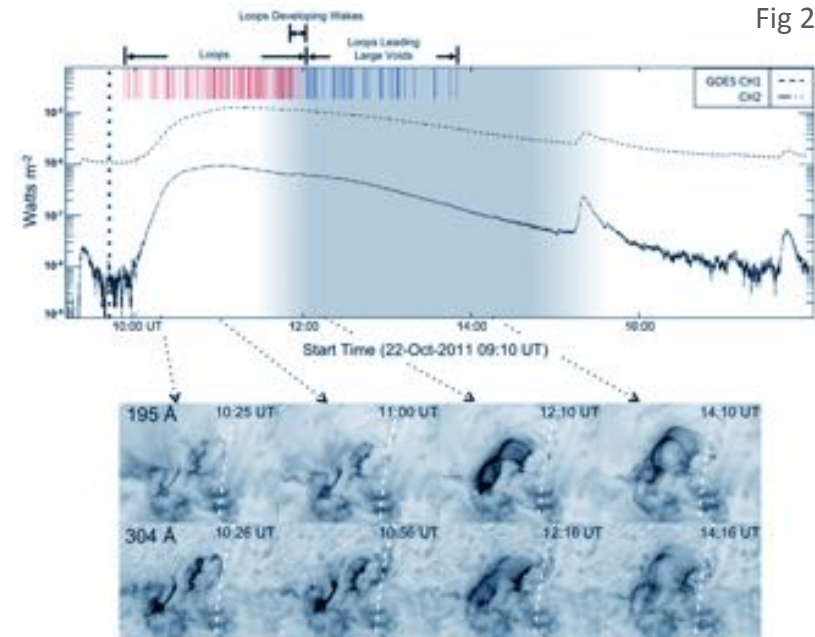
# SADs + SADLs

Fig 1



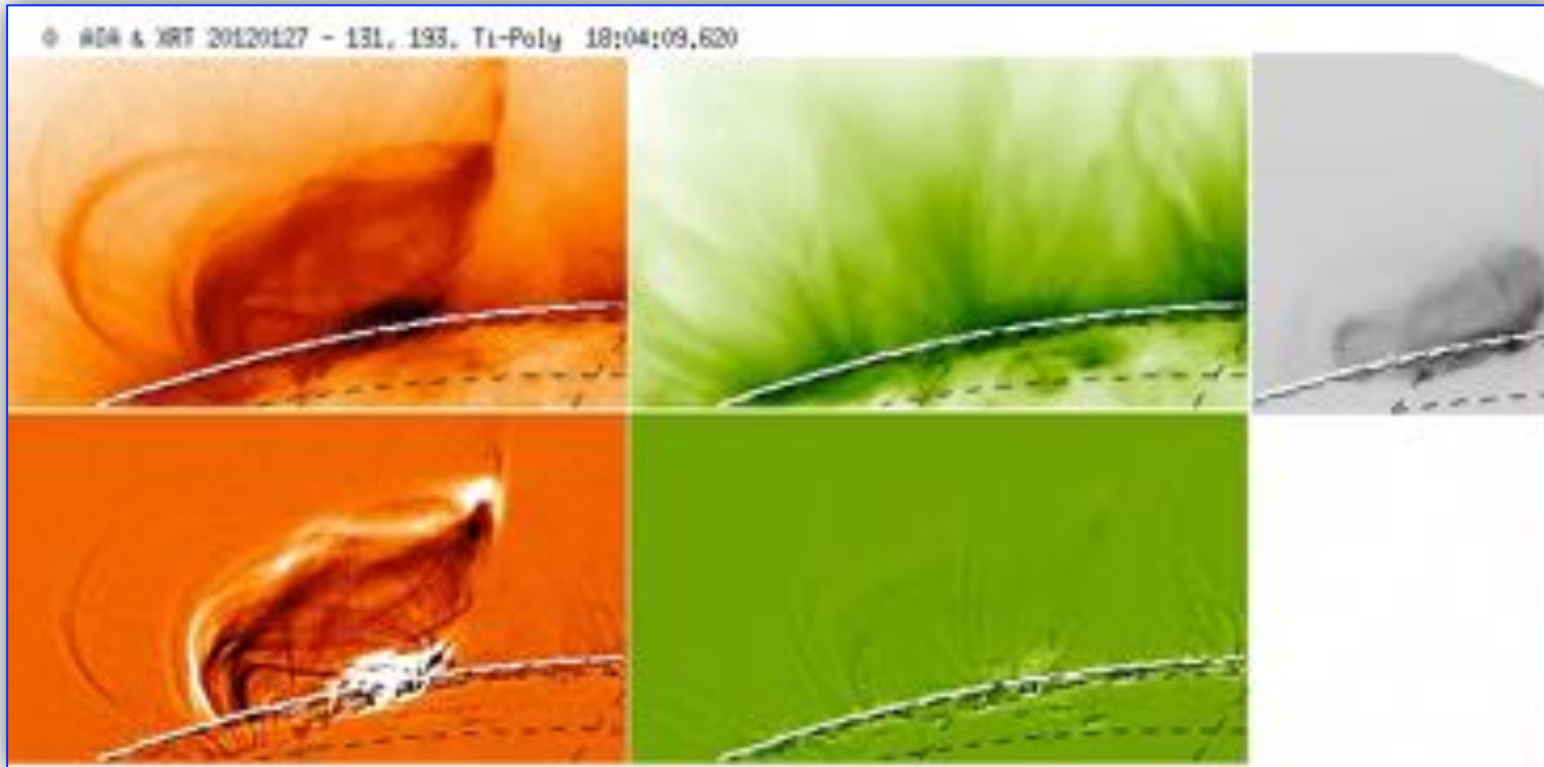
- SADs appear to be voids created by loops (SADLs) shrinking through the fan plasma.

Fig 2

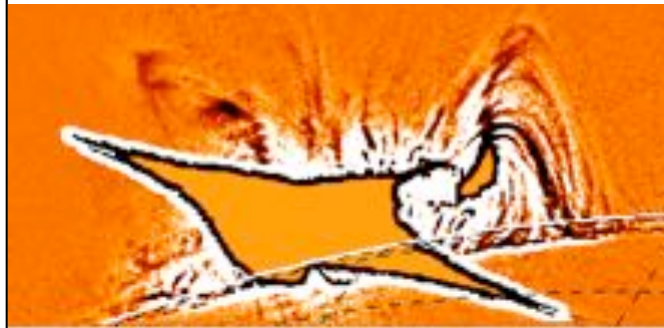




# Supra-Arcade Downflowing Loops (SADLs) Observations



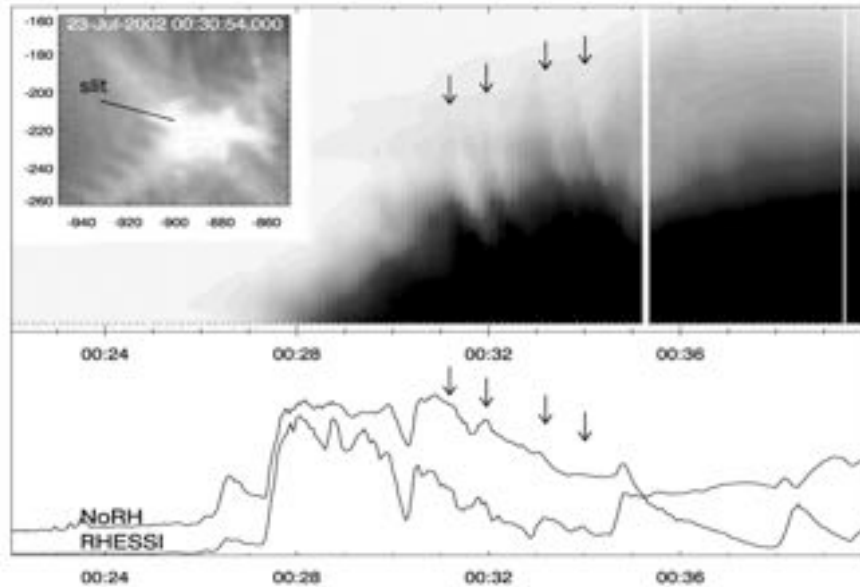
2012 Jan 27, SDO/AIA



# Particle Acceleration & Heating

RHESSI

Fig 1



VLA

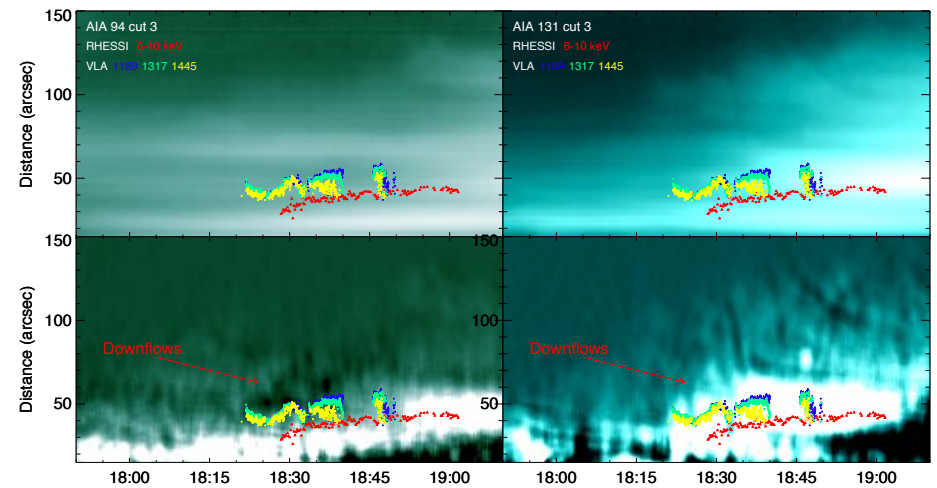
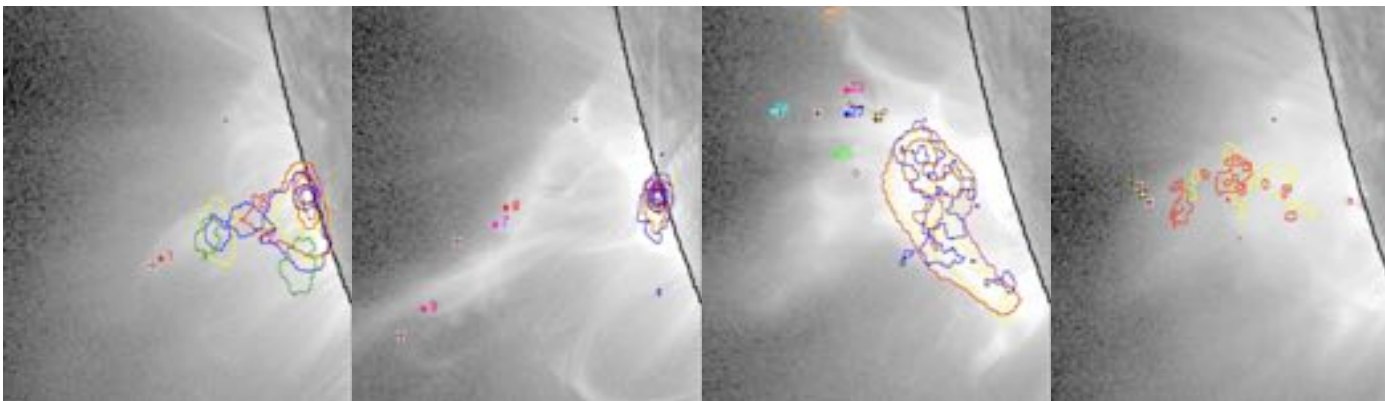


Fig 3

Fig 2



Savage – 2010 Nov 3 flare

# Diagram Models

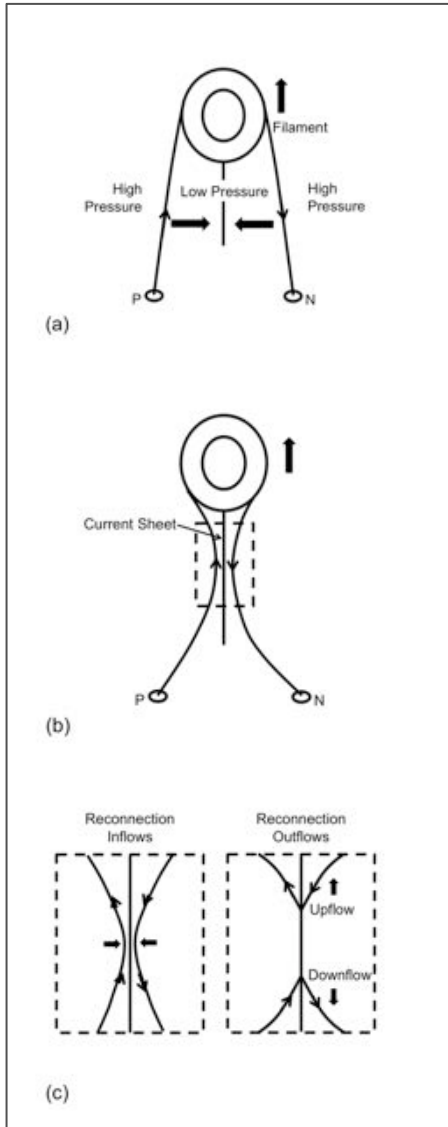


Fig 1

Fig 2

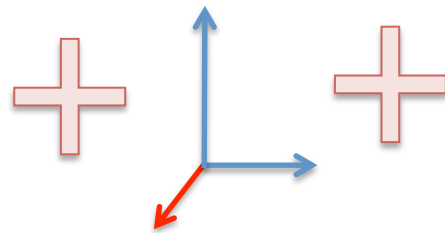
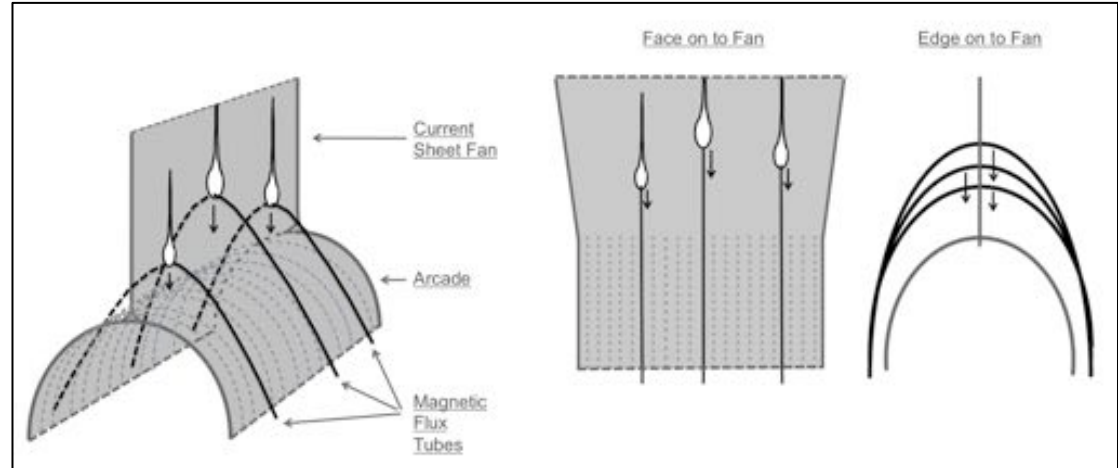


Fig 3

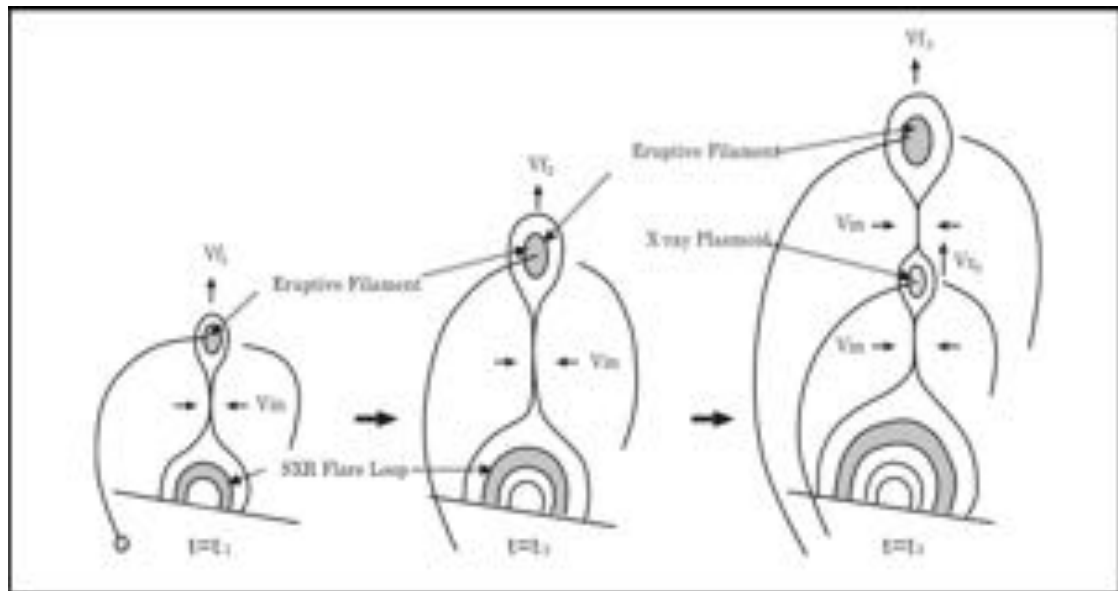


Fig 3: Ohyama & Shibata 2008

Fig 1, 2: Savage et al. 2012



# 3D is Pivotal

Fig 1

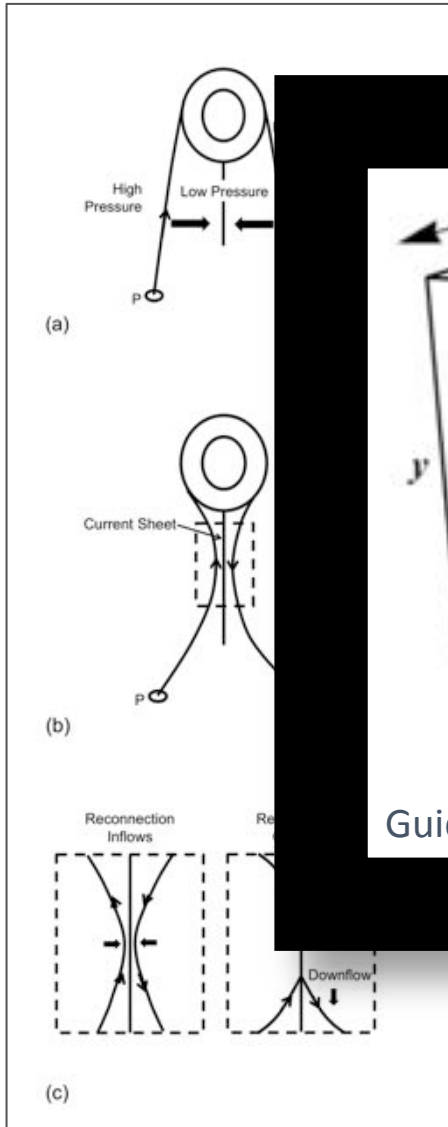
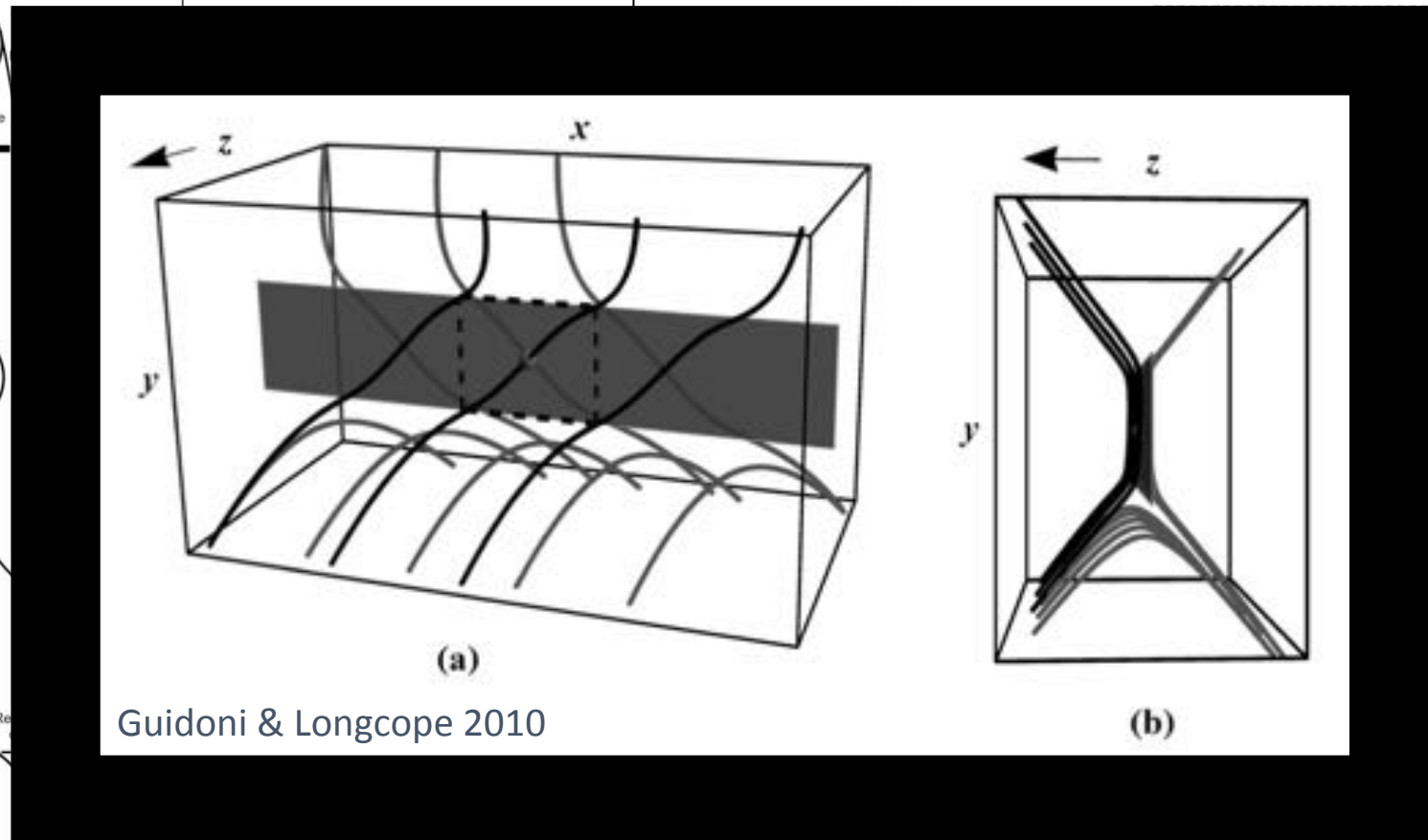
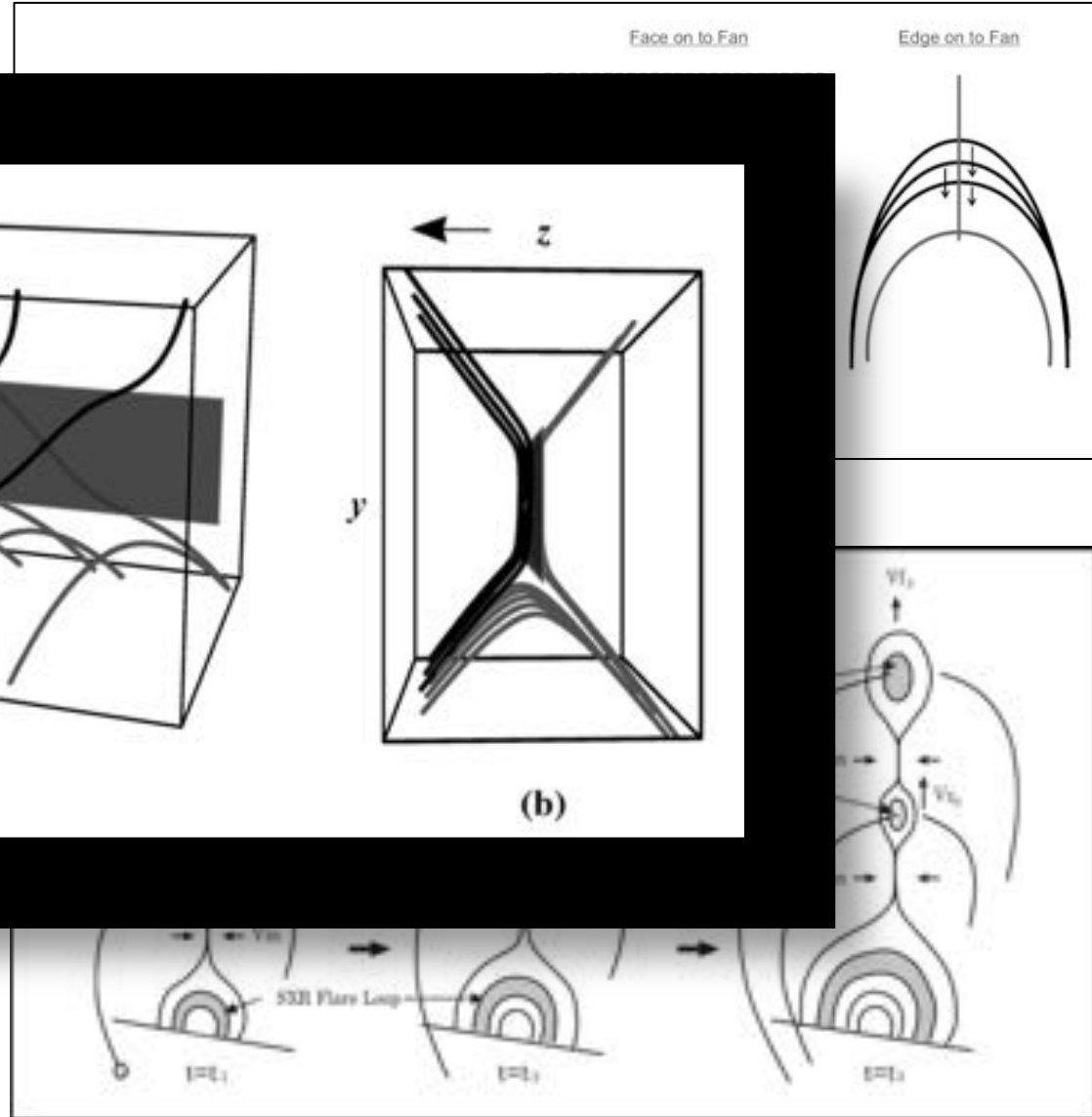


Fig 2



Guidoni & Longcope 2010

Fig 3





# Model Constraints

**OBSERVED TEMPERATURE AND DENSITY ALWAYS LOWER THAN FAN**

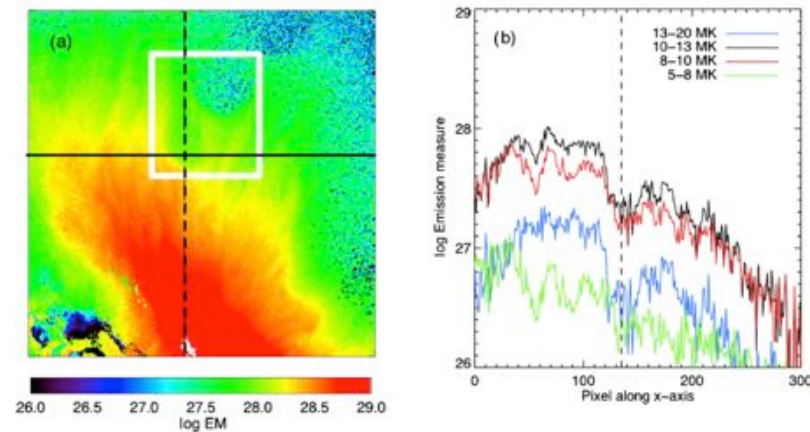


Fig 1

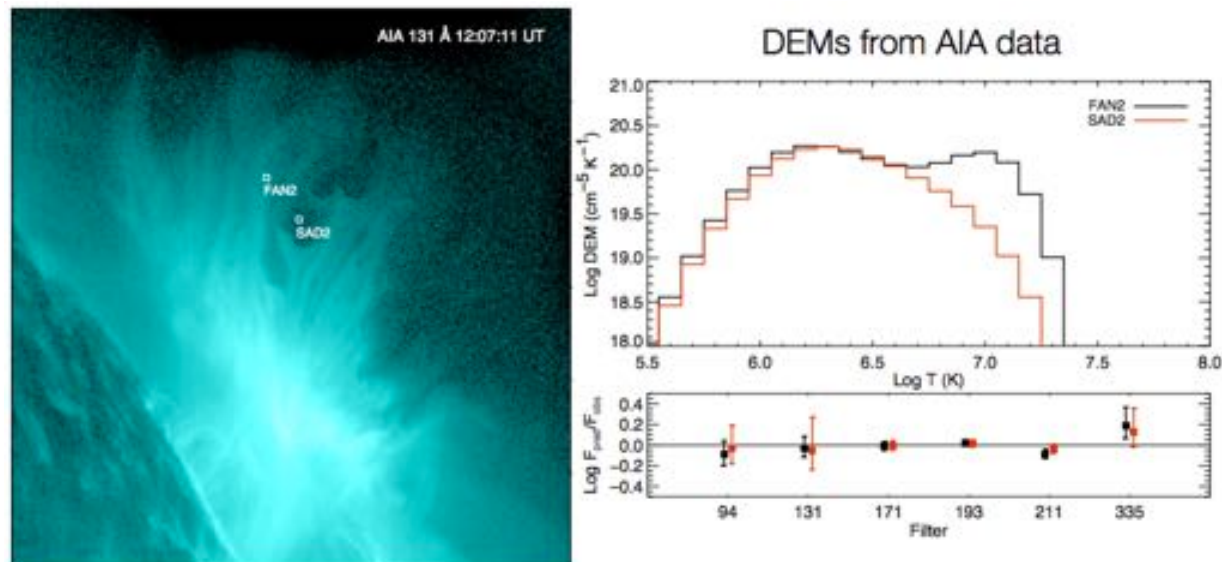
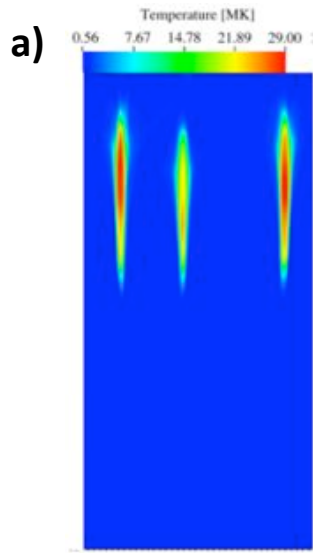


Fig 2



# Models

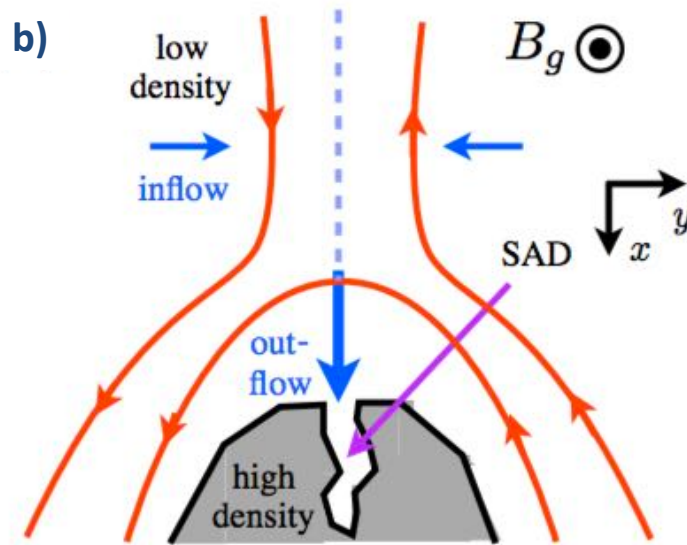


Pressure pulse + MHD wave

( $T \gg \text{fan}$ )



Too hot with respect to the surroundings

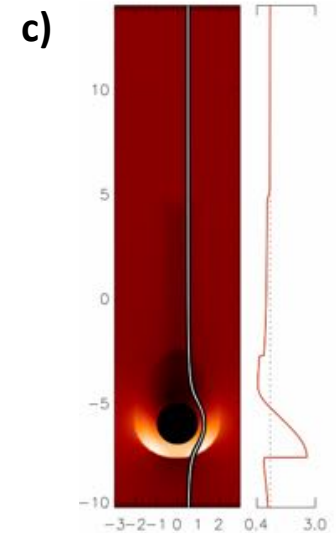


Reconnection outflows

( $T \sim < \text{fan}$ )



Incorrect geometry with respect to observations



Peristaltic pumping

( $T \sim < \text{fan}$ )

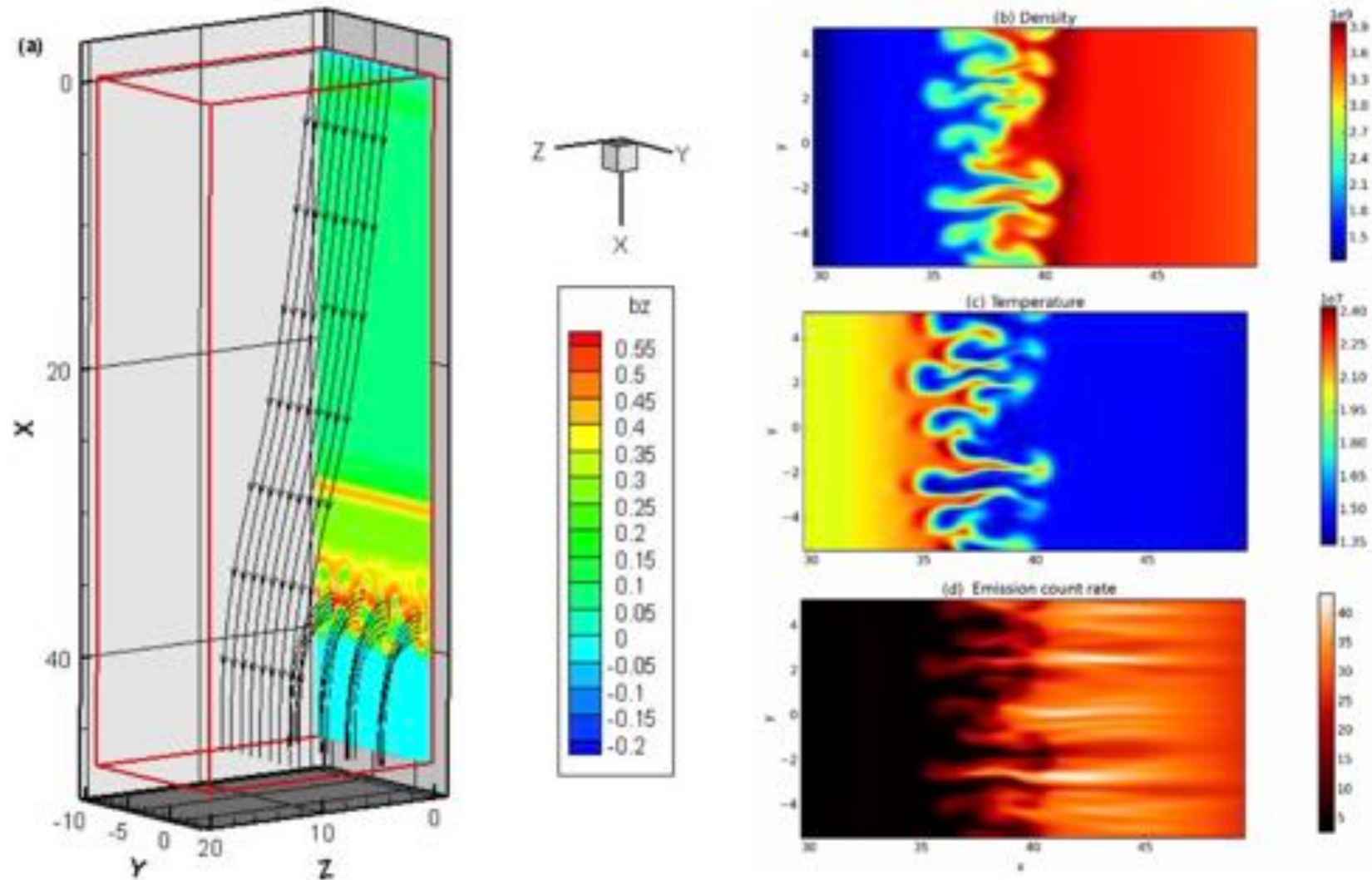
Incomplete, feasible;  
Difficult to match to observations

Fig 1: Cecere et al 2012

Fig 2: Cassak et al 2013

Fig 3: Scott et al 2013

# Models, cont.



Rayleigh-Taylor Instabilities behind retracting flux tubes ( $T > \text{fan}$ )

Too hot with respect to the surroundings

BUT

Best match to observations to date (3D!!!)  
although early in development

# SADs in the Extended Corona

Fig 1

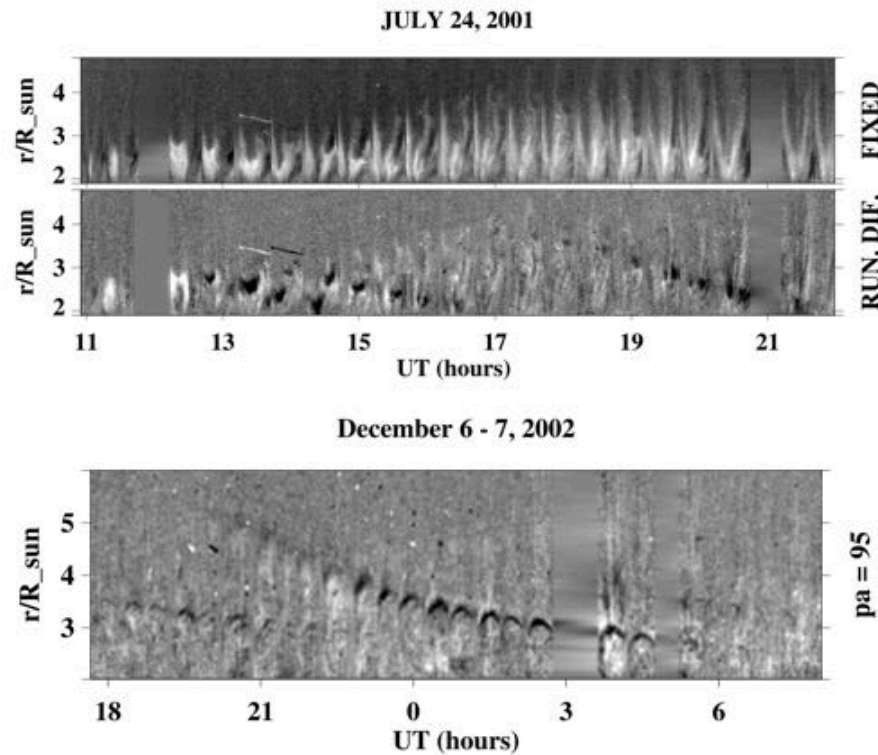
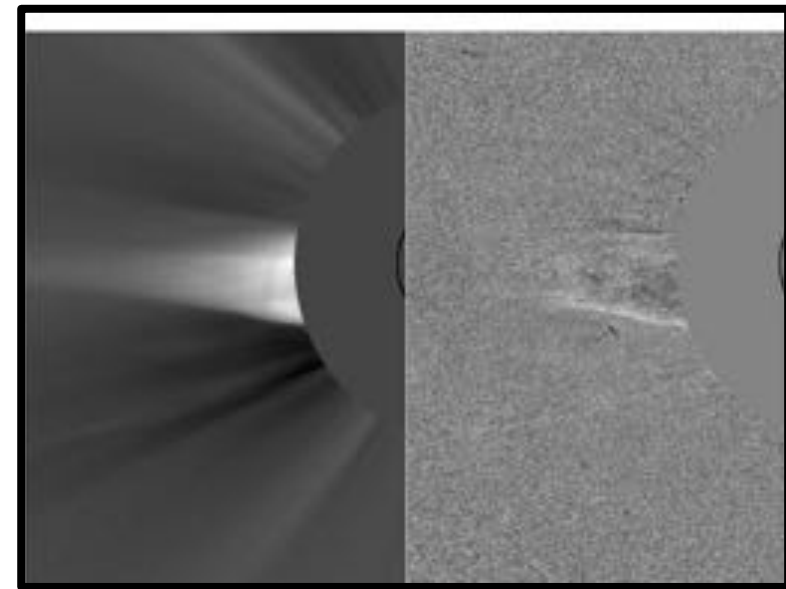
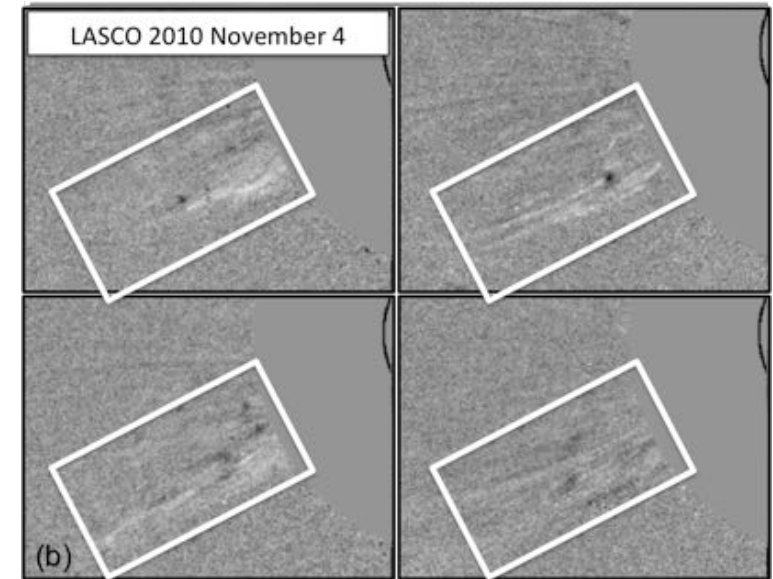
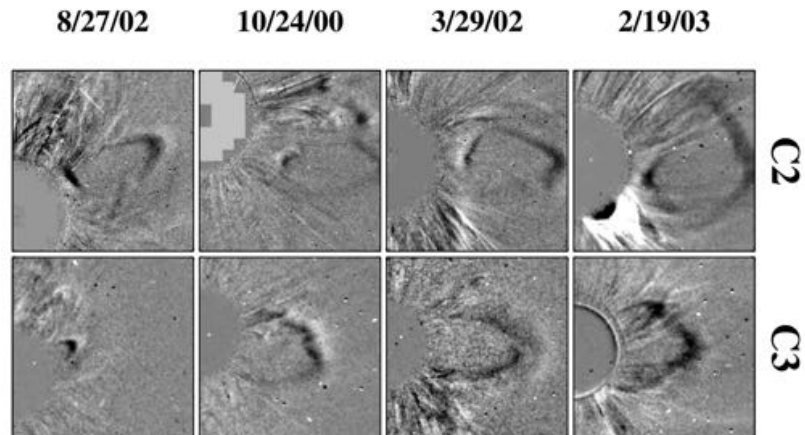


Fig 2



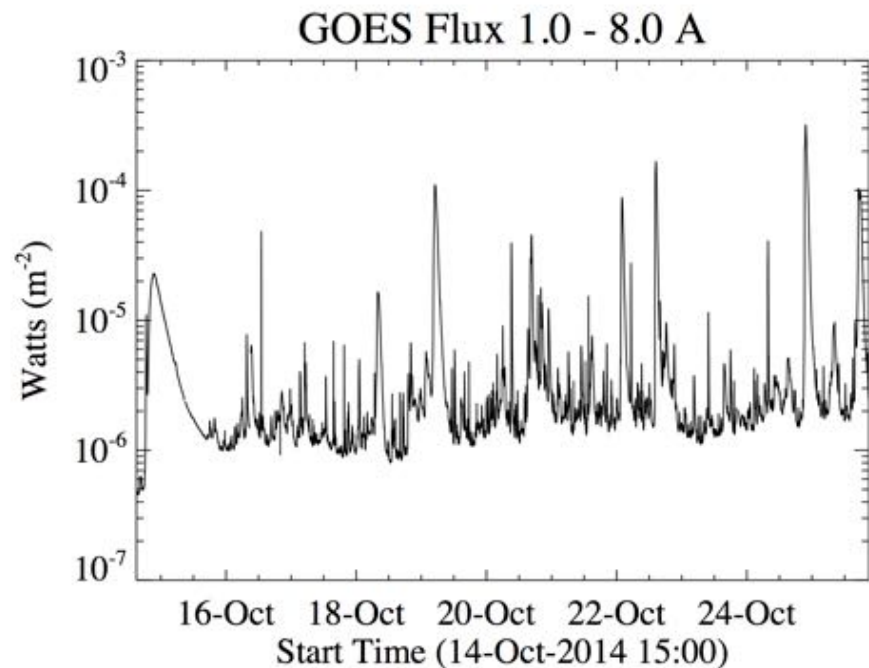


# SADs in the Extended Corona...

SADs in the lower corona are typically observed well after reconnection has occurred.

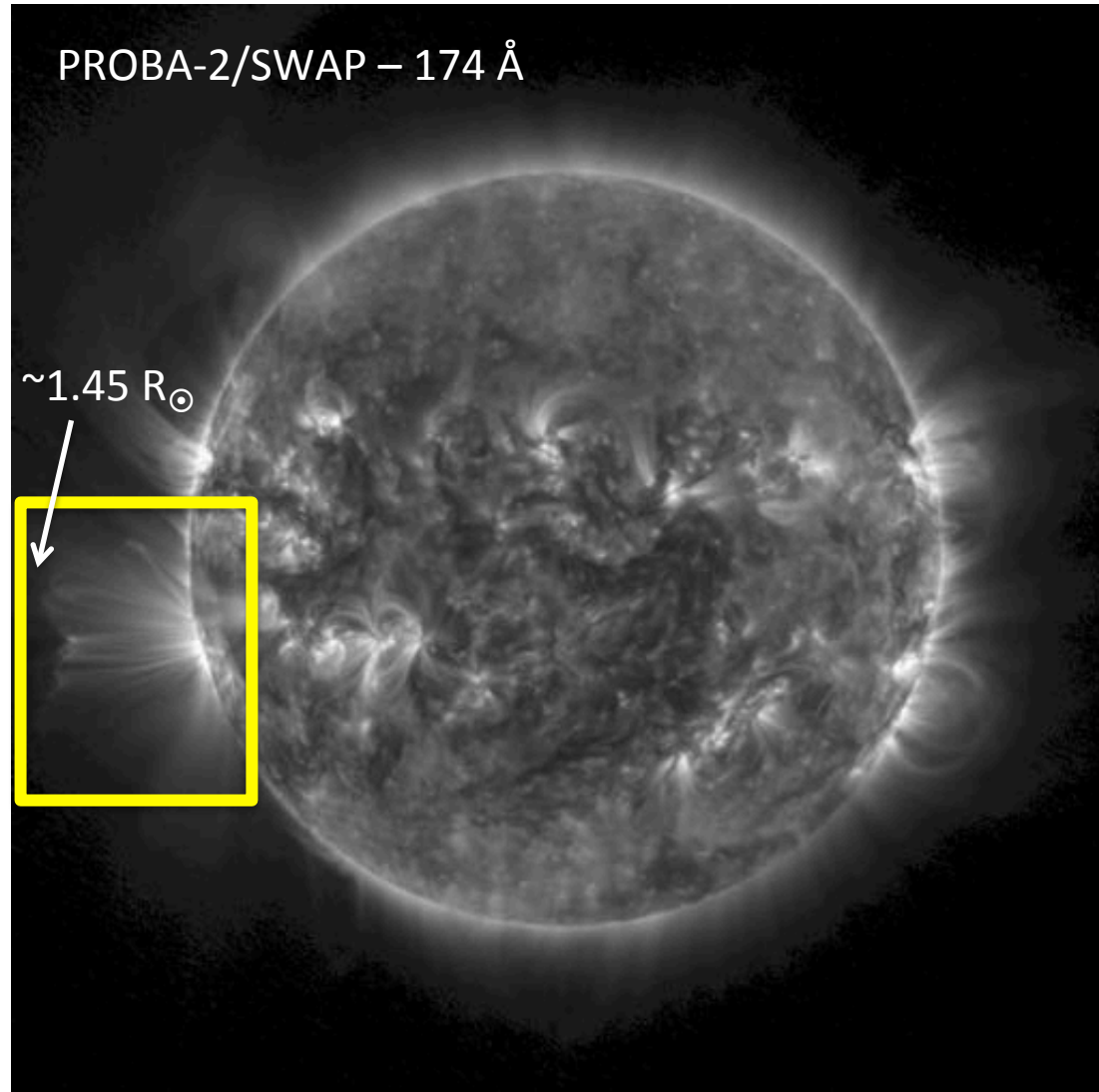
In the extended corona, we are better able to observe the migrating reconnection sites.

Coronagraphs allow us to see reconnection develop behind the CME while looking directly at the density.



“Giant Arches” Flare – 2014 Oct 14

Fig 1



# SADs in the Extended Corona...

LASCO C2  
PROBA-2/SWAP  
AIA 131 Å

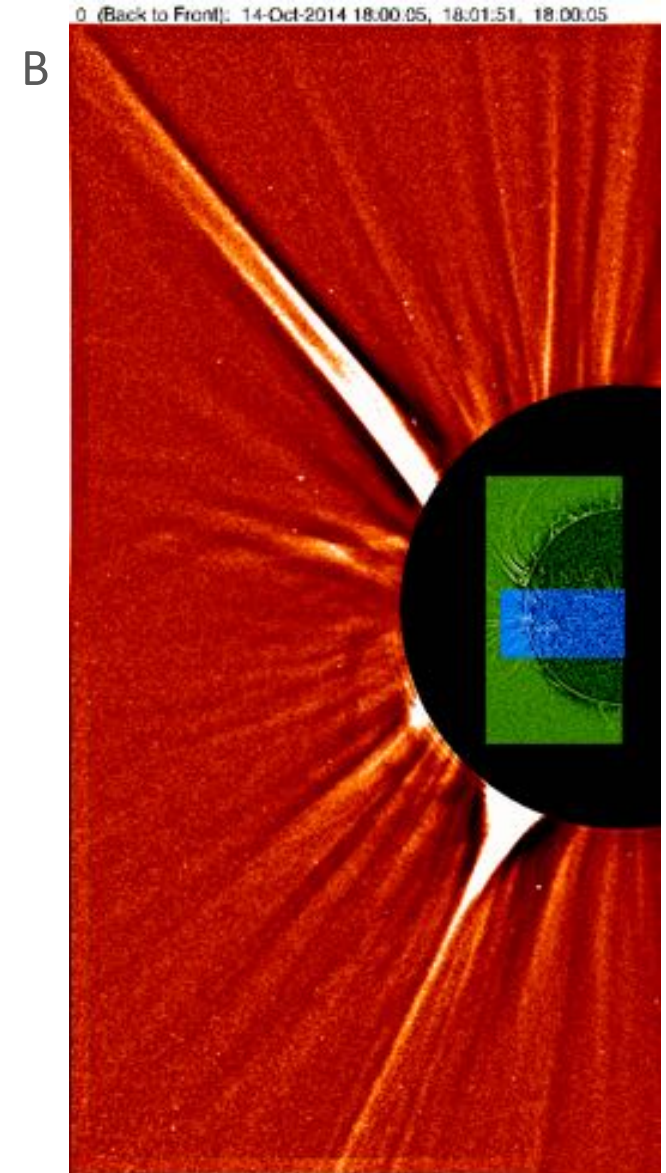
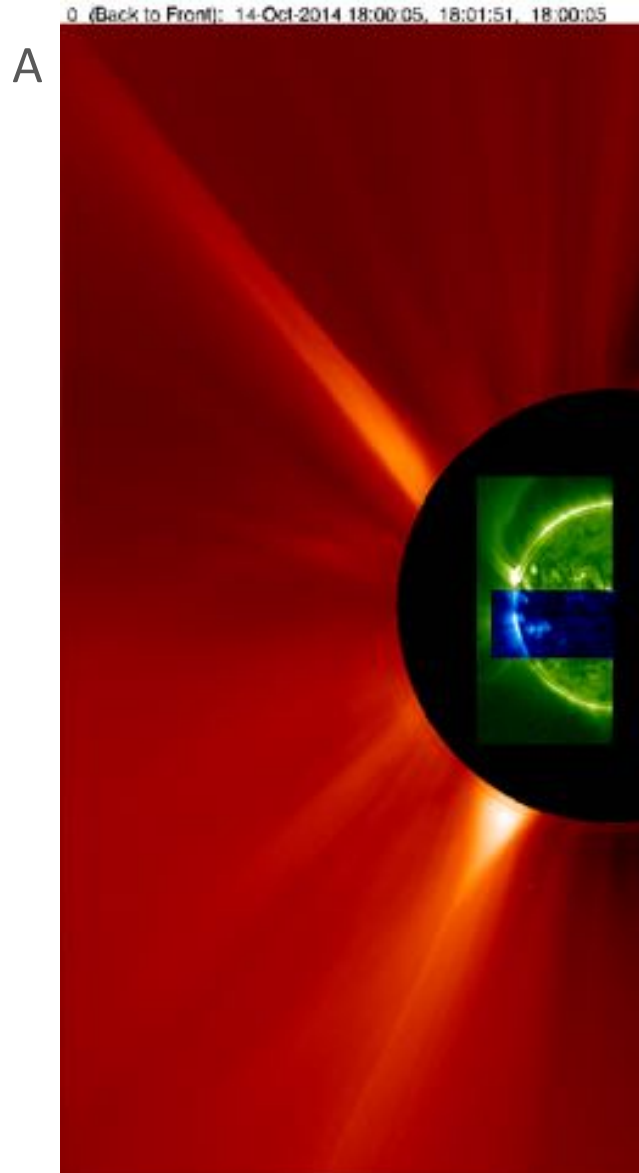
A: Flattened from a year's  
worth of data

Cleaned (cosmic  
rays, background  
stars, planets)

Attenuated disk

B: Smooth-Differenced

- Scaled



# SADs in the Extended Corona...

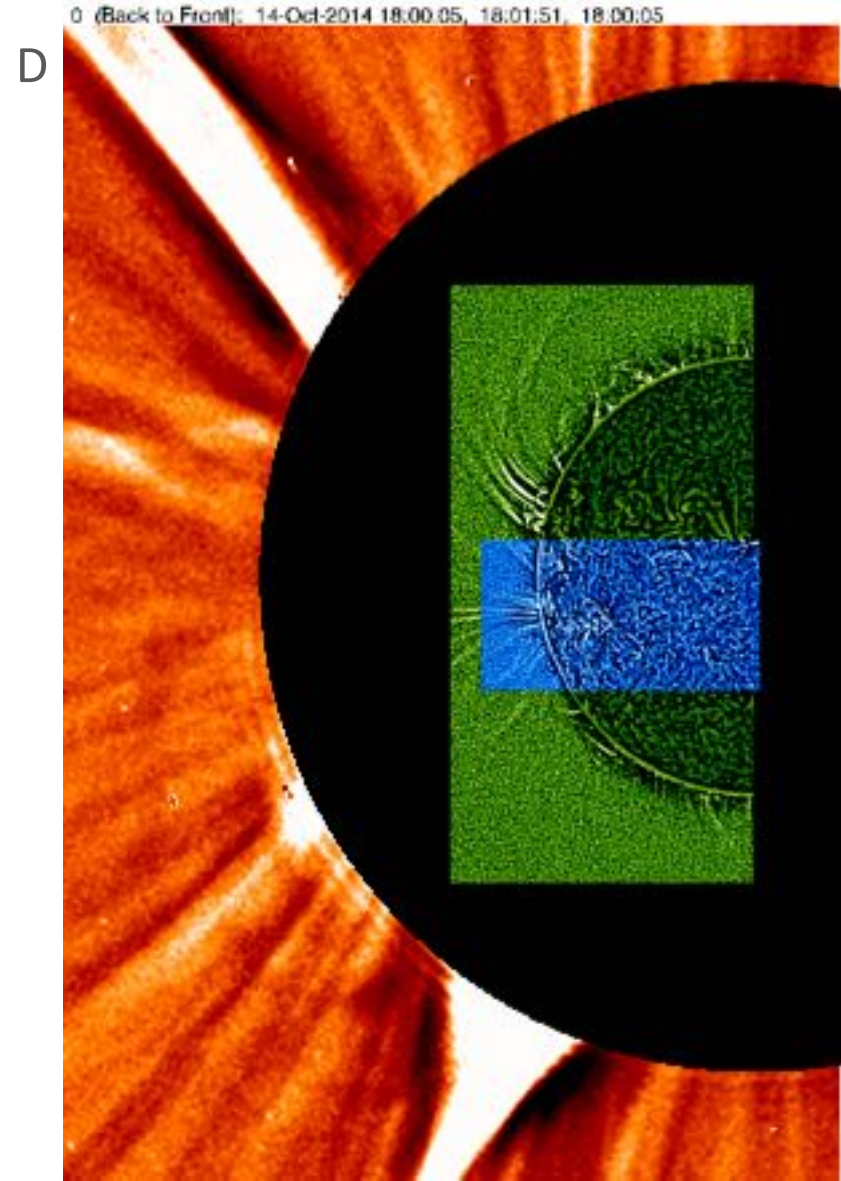
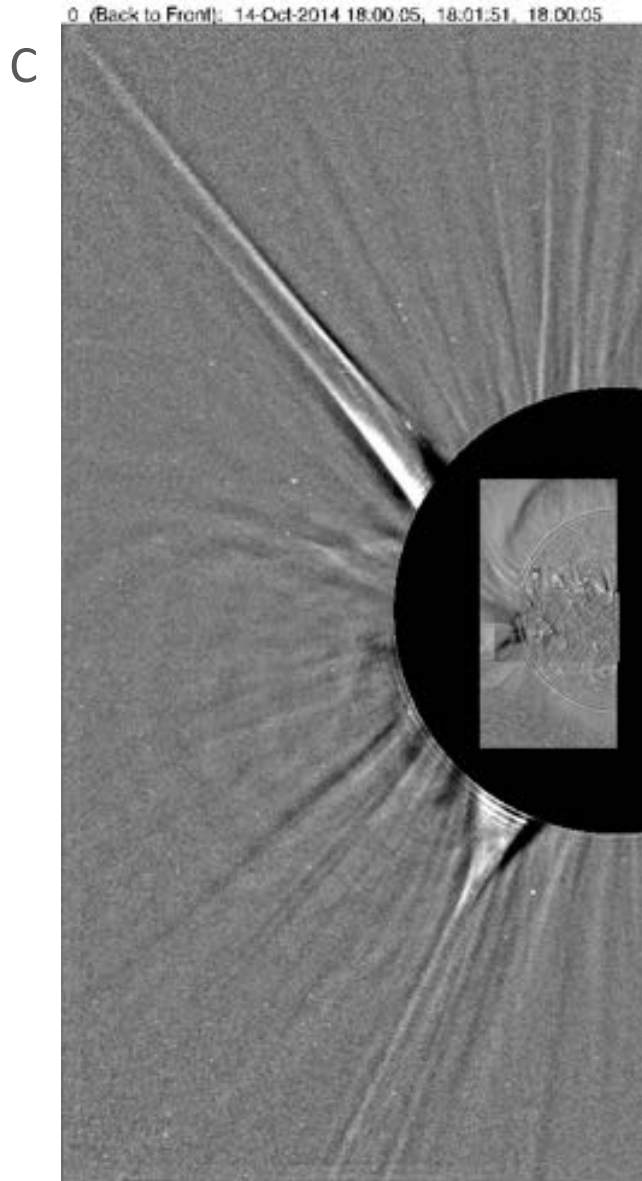
LASCO C2  
PROBA-2/SWAP  
AIA 131 Å

C: Run-Mean-Differenced

D: Smooth-Differenced

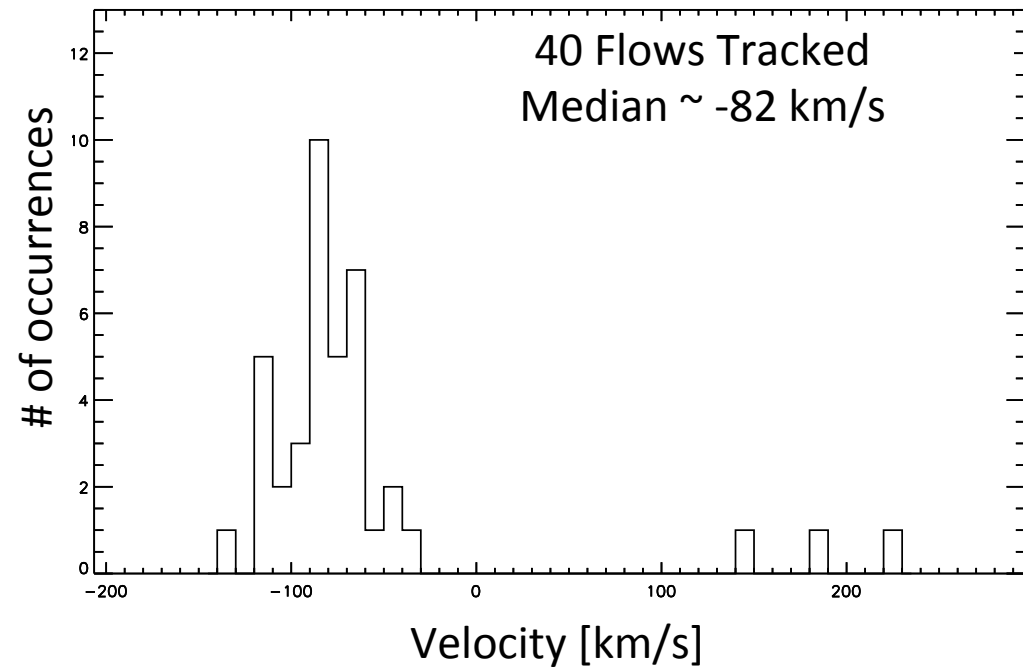
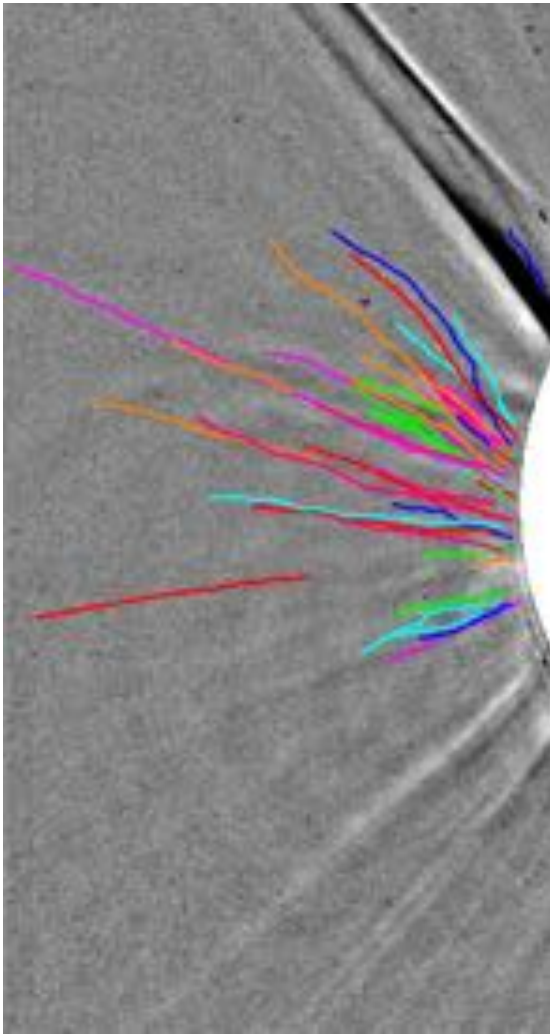
Extracted

- Scaled

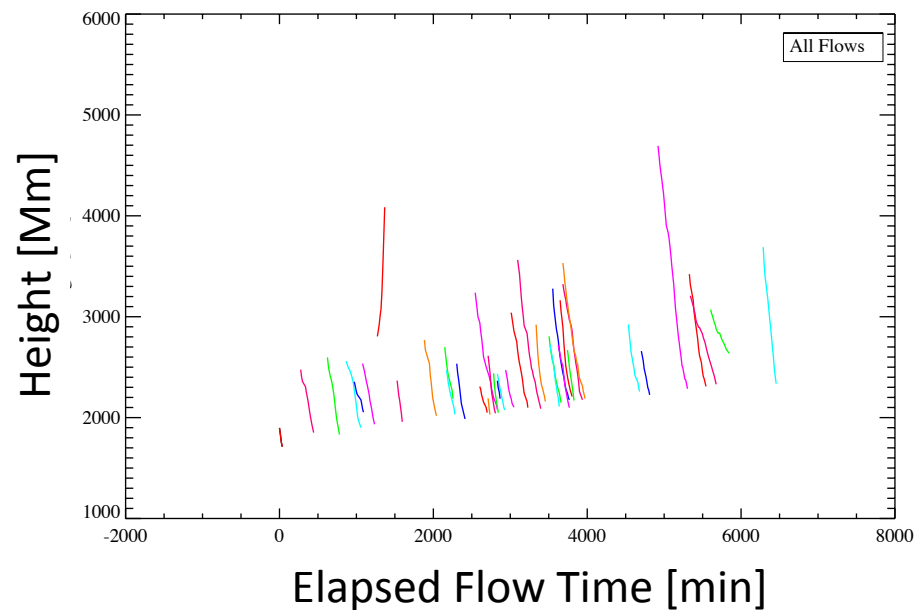
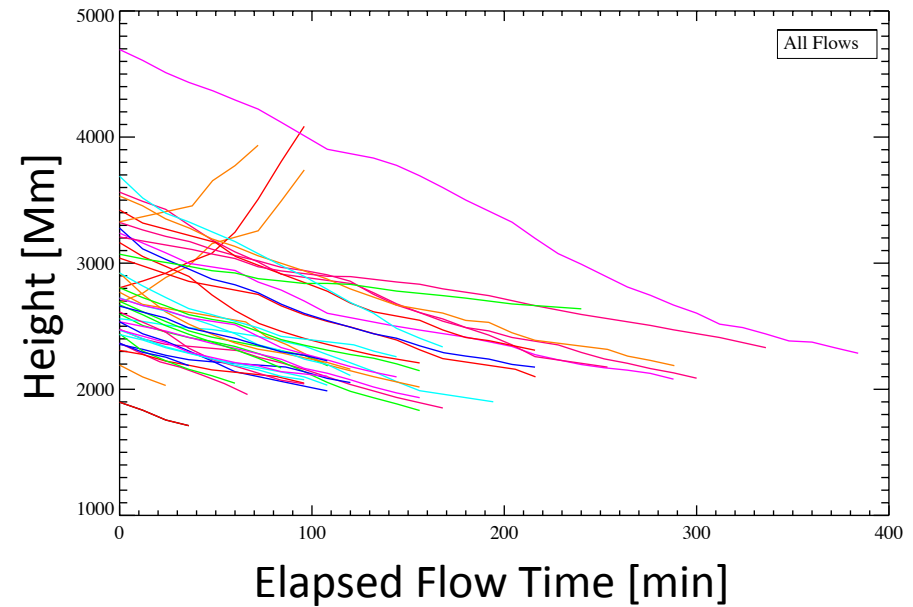
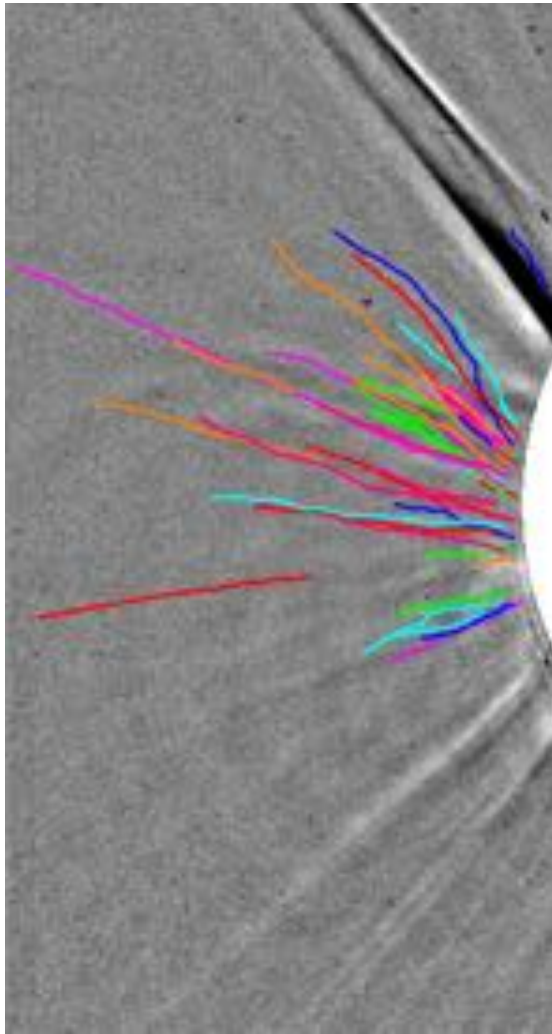




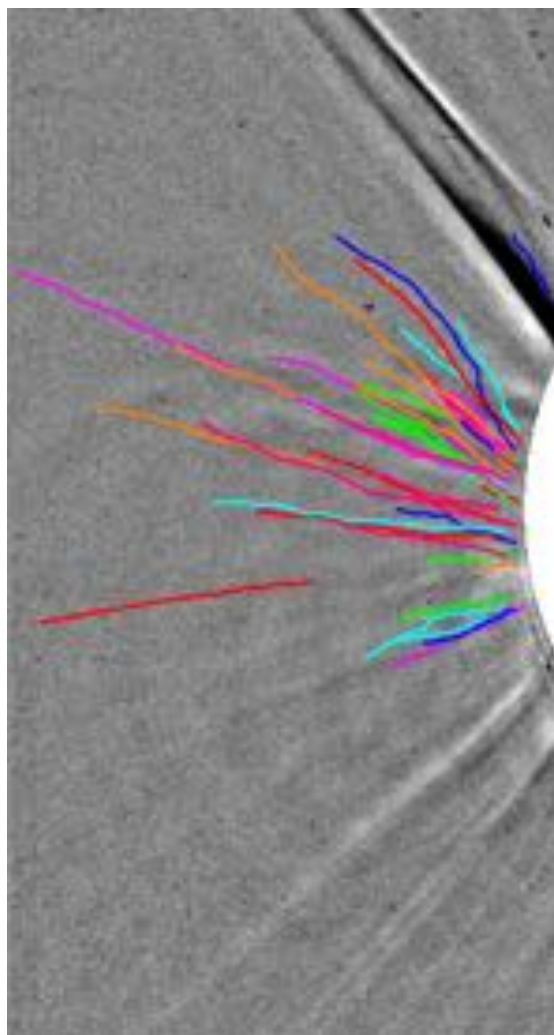
# SADs in the Extended Corona...



# SADs in the Extended Corona...

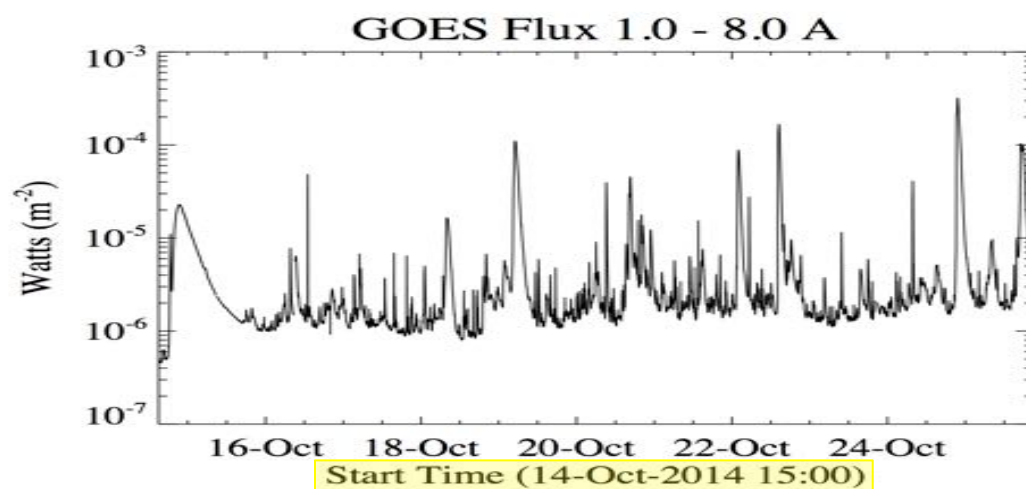
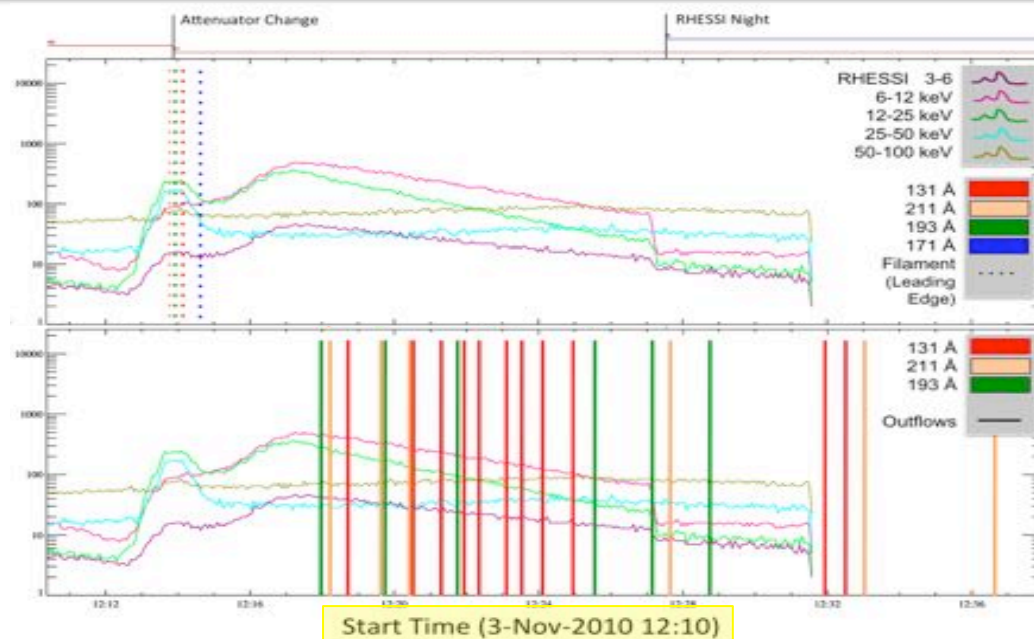


# SADs in the Extended Corona...



## TBD

Correlate flows  
directly to  
lightcurve  
as done for  
2010 Nov 3<sup>rd</sup>  
event







# Thoughts

- Continuation of shrinking loops imparts energy into the current sheet long after the flare. Clearly.
  - But for an entire week??
  - Does this happen all of the time?
  - How did this one grow so large?
    - Density stratification? Active region interactions?
- Reconnection is fast and patchy.
- Add Hinode/XRT and RHESSI data (started).
- Do features track between fields of view both ways?
  - Initial work begun. (Some even in LASCO C3.)
- Need for instrumentation to fill the gap in observing the transition corona
  - Important to be in single wavelength
  - Possibly coming to an International Space Station near you....

